

Supplemental Materials

Beyond Screen Time: The Core Influences of Problematic Screen Use on Adolescent Development Networks

Supplemental Methods	2
1. The ABCD Study and Sample Selection for The Current Study.....	2
eFigure 1. Analytic Flowchart.....	2
2. The Variables Used in the Current Study.....	3
eTable 1. Abbreviations	3
eTable 2. Definition of Variables	4
3. Cross-sectional Networks Estimation	9
4. Cross-lagged Penal Networks (CLPNs) Estimation	9
5. Nonparametric Bootstrap Method.....	9
Supplemental Results.....	10
1. Description of variables.....	10
eFigure 2. Missing Data of 2-year follow-up Cross-Sectional Network Analysis	10
eFigure 3. Missing Data of 4-year follow-up Cross-Sectional Network Analysis	11
eFigure 4. Missing Data of CLPN Analysis.....	12
eTable 3. Description of T2 Cross-Sectional Network Analysis Variables.....	13
eTable 4. Description of T4 Cross-Sectional Network Analysis Variables.....	14
eTable 5. Description of CLPN Analysis Variables	15
eFigure 5. Data Distribution of Screen Usage Measurements.....	17
2. Cross-sectional Networks.....	18
eFigure 6. Network comparison of cross-sectional networks.....	18
eFigure 7. Bootstrapped Edge-Weight Accuracy Test of Cross-Sectional Networks	18
eFigure 8. Case-Dropping Bootstrapped Centrality Indices for Cross-Sectional Networks	19
eTable 6. Top 10 Edges of Cross-Sectional Networks Based on Bootstrapping	20
eTable 7. Comparison of Node Centrality Differences Between Cross-Sectional Networks.....	22
eFigure 9. Difference Test of Strength in Cross-Sectional Networks.....	23
eFigure 10. Difference Test of EI in Cross-Sectional Networks.....	24
eFigure 11. Difference Test of Bridge Strength in Cross-Sectional Networks	25
3. Cross-lagged Penal Networks (CLPNs).....	26
eFigure 12. Case-Dropping Bootstrapped Centrality Indices for CLPNs.....	26
eFigure 13. CLPNs Without Thresholds.....	26
eTable 8. Top 10 Edges of CLPNs Based on Bootstrapping.....	27
eFigure 14. Difference Test of Out- and In-Strength in CLPNs	28
eFigure 15. Difference Test of Out-EI and In-EI in CLPNs	29
eFigure 16. Difference Test of Bridge Strength in CLPNs	29
4. Sensitivity Analyses for Imputation	30
eTable 9. Demographics of the Sample After Pairwise Deletion.....	30

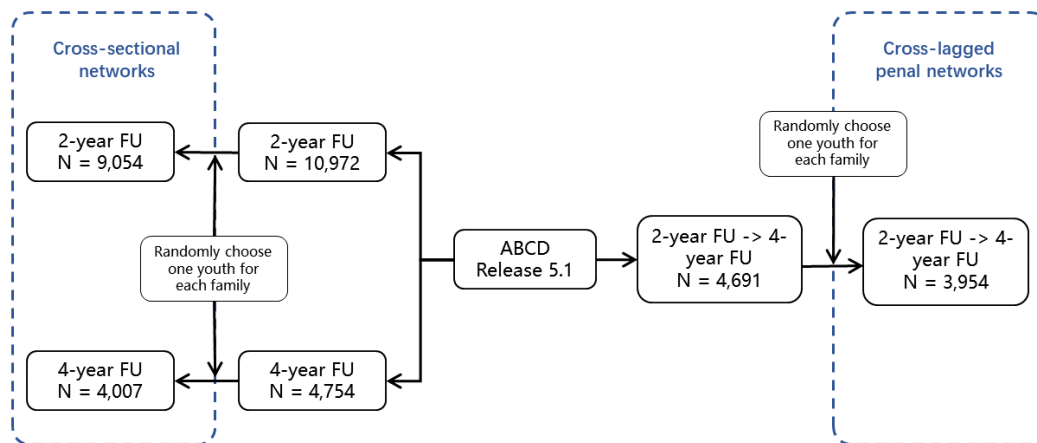
eTable 10. Demographics of the Sample After Pairwise Deletion.....	31
eFigure 17. Cross-Sectional Networks After Pairwise Deletion.....	32
eFigure 18. CLPNs After Pairwise Deletion.....	32
5. Sensitivity Analyses for Problematic Usage.....	33
eTable 11. Classification of Problematic Screen Usage.....	34
eFigure 19. Transition of Problematic Screen Usage.....	35
eTable 12. Classification of the Sample in Cross-sectional Networks	36
eTable 13. Classification of the Sample in CLPN Models	36
eFigure 20. Cross-Sectional Networks for Classification Data	37
eFigure 21. CLPNs for Classification Data	37
References	38

Supplemental Methods

1. The ABCD Study and Sample Selection for The Current Study

The ABCD study recruited ~11,800 children aged 9-10 years from 22 sites, aiming to create a population-level, diverse cohort over a decade of life during the transition from childhood to early adulthood and to provide practical information to promote the well-being of children. The study sites include Children's Hospital Los Angeles; Florida International University; Laureate Institute for Brain Research; Medical University of South Carolina; Oregon Health and Science University; SRI International, Menlo Park; University of California, San Diego; University of California, Los Angeles; University of Colorado Boulder; University of Florida; University of Maryland, Baltimore; University of Michigan; University of Minnesota; University of Pittsburgh; University of Rochester; University of Utah; University of Vermont; University of Wisconsin-Milwaukee; Virginia Commonwealth University; Washington University in St. Louis; and Yale University. The details of the sampling rationale, methods and procedures are publicly available (Garavan et al., 2018). The coordinating center, located at the University of California, obtained ethical approval of the ABCD protocols. All caregivers provided written informed consent and all children provided assent to participate in the study.

eFigure 1. Analytic Flowchart



Note. FU: follow-up

2. The Variables Used in the Current Study

All abbreviations of variables used in this article are listed in eTable 1. The demographic variables included in the current study have been coded as either categorical variables (dummy-coded) or ordinal variables (rank-coded). Details and full descriptions of variables are publicly available on the NIMH Data Archive website. We followed the codes and recommendations from the ABCD Data Analytics and Informatics Resource Center (DAIRC) to preprocess the ABCD 5.1 release tabulated data and to recode the demographic variables. Detailed variable data preprocessing information and code can be found in our previous research (Song et al., 2023). A data dictionary providing detailed definitions of all the variables can be accessed at <https://data-dict.abcdstudy.org/>. Below we provide comprehensive descriptions of variables we used in the current study.

eTable 1. Abbreviations

Abbreviations	Full name	Abbreviations	Full name
A1 (VGAQ)	Video Game Addiction Questionnaire	CLPN	cross-lagged panel network
A2 (SMAQ)	Social Media Addiction Questionnaire	DPI	Delinquent Peer Involvement
A3 (MPIQ)	Mobile Phone Involvement Questionnaire	E1	Family Conflict
B1	video game time	E2	Prosocial Peers (RE)
B2	social media time	E3	Rule-Breaking Peers
B3	TV time	E4	School Environment (RE)
B4	checking behavior	E5	School Involvement (RE)
BAS	behavioral activation system	E6	School Disengagement
BIS	behavioral inhibition system	EBIC	Extended Bayesian Information Criterion
C1	anxious/depressed	EI	expected influence
C2	withdrawn/depressed	FES	Family Environment Scale
C3	somatic complaints	GGM	Gaussian graphical model
C4	social problems	PBP	Peer Behavior Profile
C5	thought problems	PPI	Prosocial Peer Involvement
C6	attention problems	SRPF	School Risk and Protective Factors
C7	rule-breaking behavior	STQ	Screen Time Questionnaire
C8	aggressive behavior	UPPS	urgency, perseverance, premeditation, and sensation-seeking
CBCL	Child Behavior Checklist		

eTable 2. Definition of Variables

Variable	ABCD Study assessment	Description
Demographic		
Age (Parent Report)	ABCD Demographics Survey	Chronological age in months.
Sex (Parent Report)	ABCD Demographics Survey	Assigned sex of the child at birth: Female or male.
Race (Parent Report)	ABCD Demographics Survey	A parent reported the race of the child by answering “What race do you consider the child to be?” The choice of this question recoded into a 4-level categorical variable: White, Black, Asian, Mixed/Other.
Ethnicity (Parent Report)	ABCD Demographics Survey	The parent-reported ethnicity of a child was recoded into a 2-level categorical variable Hispanic or Non-Hispanic, based on the question “Do you consider the child Hispanic/ Latino/ Latina?”
Parents' Marital Status (Parent Report)	ABCD Demographics Survey	A parent answered: “Are you now married, widowed, divorced, separated, never married or living with a partner?” The response was recoded as a 2-level categorical variable: Married or living with a partner or Single.
Parental Highest Education (Parent Report)	ABCD Demographics Survey	The parental highest education came from parent-reported information about their and their partner's (if there was one) highest grade or level of schooling they completed. The responses were recoded into a 2-level categorical variable: High school or less and College education or more.
Family Income	ABCD Demographics Survey	Participants answered: “What is your TOTAL COMBINED FAMILY INCOME for the past 12 months?” Responses were coded as: <\$25k, \$25k-<\$50k, \$50k-<\$75k, \$75k-<\$100k, \$100k-<\$200k, \$200k+.
Screen Usage Measurement		
Screen Time – Video game time	ABCD Youth Screen Time Questionnaire	Youth reported how much they played video games (i.e., single-player video games or multiplayer video games) on weekdays and weekends in the drop-list for hours (0 to 23 hours) and minutes (0, 15, 30, 45) since the 2-year follow-up. The average daily time spent on gaming was calculated by a weighted average $(5 * \text{weekdays} + 2 * \text{weekends}) / 7$.
Screen Time – Social	ABCD Youth Screen Time	Youth reported how much they used social media (i.e.,

Media time	Questionnaire	social networking, texting, and video chatting) on weekdays and weekends in the drop-list for hours (0 to 23 hours) and minutes (0, 15, 30, 45) since the 2-year follow-up. The average daily time spent on social media was calculated by a weighted average $(5 \times \text{weekdays} + 2 \times \text{weekends}) / 7$.
Screen Time – TV time	ABCD Youth Screen Time Questionnaire	Youth reported how much they watch or stream TV shows or movies on weekdays and weekends in the drop-list for hours (0 to 23 hours) and minutes (0, 15, 30, 45) since the 2-year follow-up. The average daily time spent on social media was calculated by a weighted average $(5 \times \text{weekdays} + 2 \times \text{weekends}) / 7$.
Mobile Phone Checking Behavior (Child Report)	Mobile Phone Attachment	Youth reported their mobile phone attachment since the 2-year follow-up by answering “On a scale of 1-10 (with 1 = barely check it/can go days without it, and 10 = check at least hourly when awake), how attached are you to your phone?”
Problematic Video Game Use (Child Report)	Videogame Addiction Questionnaire (VGAQ)	The 6-item scale was adapted from the Bergen Facebook Addiction Scale (Andreassen et al., 2012). The average score indicates the degree of problematic video game use since the 2-year follow-up. Every item was scored from 1 = never to 6 = very often.
Problematic Social Media Use (Child Report)	Social Media Addiction Questionnaire (SMAQ)	The 6-item scale was adapted from the Bergen Facebook Addiction Scale (Andreassen et al., 2012). The average score indicates the degree of problematic social media use since the 2-year follow-up. Every item was scored from 1 = never to 6 = very often.
Problematic Mobile Phone Use (Child Report)	Mobile phone involvement questionnaire (MPIQ)	Eight 7-point scales (1 = Strongly disagree, 7 = Strongly agree) assessed problematic mobile phone use since the 2-year follow-up. A higher average score indicated more problematic use.
Psychopathology		
Psychopathological Problem Behaviors (Parent Report)	Child Behavior Checklist (CBCL)	The CBCL comprises 113 items rated on a 3-point scale (not true, somewhat true, and very true). T-scores for eight problem behaviors (anxious/ depressed, withdrawn/ depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, and aggressive behavior) were included.
Behavioral Tendencies		

Impulsivity (Child Report)	Urgency, Premeditation, Perseverance, Sensation Seeking, Positive Urgency, Impulsive Behavior Scale for Children-Short Form (UPPS-P)	The 20-item UPPS-P scale assessed five facets of impulsivity. A higher sum score indicates a higher level of impulsivity.
Behavioral Activation System (Child Report)	Behavioral Avoidance/Inhibition System Scales (BIS/BAS) - BAS Subscale	The ABCD-modified sum score of three BAS subscales was utilized: BAS drive, BAS reward responsiveness, and BAS fun-seeking.
Behavioral Inhibition System (Child Report)	Behavioral Avoidance/Inhibition System Scales (BIS/BAS) - BIS Subscale	The ABCD modified sum score of the BIS subscale was utilized.
Environmental Factor		
Family Conflict (Child Report)	ABCD Family Environment Scale - Family Conflict Subscale	Youth answered nine questions on whether there had been conflict in the family in the past year. A higher sum score indicates greater conflict.
Involvement With Prosocial Peers (Child Report)	ABCD Peer Behavior Profile	Three 5-point items (1 = None or almost none, 5 = All or almost all) assessed the extent to which the youth's friendship network consists of prosocial peers (e.g., friends who are excellent students, athletes, etc.)
Involvement With Rule-Breaking/Delinquent Peers (Child Report)	ABCD Peer Behavior Profile	Three 5-point items (1 = None or almost none, 5 = All or almost all) assessed the extent to which the youth's friendship network consists of rule-breaking/delinquent peers (e.g., friends who skip school, shoplift, etc.)
School Disengagement (Child Report)	ABCD School Risk and Protective Factors Survey - Disengagement Subscale	Two 4-point scoring (1 = strongly disagree, 4 = strongly agree) questions reflect alienation from academic goals. The sum of the responses was used; higher values denote greater disengagement.
Positive School Involvement (Child Report)	ABCD School Risk and Protective Factors Survey - Involvement Subscale	Four 4-point scoring (1 = strongly disagree, 4 = strongly agree) questions reflect positive school involvement. The sum of the responses was used; higher values denote greater engagement in academic activities.
Positive View of School Environment (Child Report)	ABCD School Risk and Protective Factors Survey - Environment Subscale	Six 4-point scoring (1 = strongly disagree, 4 = strongly agree) questions reflect the experience of school as an opportunity and support environment. The sum of the responses was used; higher values denote a more positive view of the school environment

eTable 3. Dimensions of Gaming Disorder Diagnostic Criteria

Dimension	Diagnostic Criteria
DSM-5	
Salience	1. The individual thinks about previous gaming activity or anticipates playing the next game; Internet gaming becomes the dominant activity in daily life.
Withdrawal	2. These symptoms are typically described as irritability, anxiety, or sadness, but there are no physical signs of pharmacological withdrawal.
Tolerance	3. The need to spend increasing amounts of time engaged in Internet games.
Loss of control	4. Unsuccessful attempts to control the participation in Internet games.
Proiority	5. Loss of interests in previous hobbies and entertainment as a result of, and with the exception of, Internet games.
Continuation	6. Continued excessive use of Internet games despite knowledge of psychosocial problems.
Deception	7. Has deceived family members, therapists, or others regarding the amount of Internet gaming.
Mood modification	8. Use of Internet games to escape or relieve a negative mood (e.g., feelings of helplessness, guilt, anxiety).
Conflict	9. Has jeopardized or lost a significant relationship, job, or educational or career opportunity because of participation in Internet games.
ICD-11	
Loss of control	1. Impaired control over gaming behaviour (e.g., onset, frequency, intensity, duration, termination, context).
Proiority	2. Increasing priority given to gaming behaviour to the extent that gaming takes precedence over other life interests and daily activities.
Continuation despite conflict	3. Continuation or escalation of gaming behaviour despite negative consequences (e.g., family conflict due to gaming behaviour, poor scholastic performance, negative impact on health).

Note. The dimensions presented in this table are based on established diagnostic criteria for Gaming Disorder as outlined in the DSM-5 and ICD-11 (American Psychiatric Association, 2013; World Health Organization, 2018).

eTable 4. Dimensions of Problematic Screen Use Scale

Dimension	Scale Item
Video Game Addiction Questionnaire / Social Media Addiction Questionnaire	
Salience	1. I spend a lot of time thinking about playing video games. / I spend a lot of time thinking about social media apps or planning my use of social media apps.
Tolerance	2. I feel the need to play video games more and more. / I feel the need to use social media apps more and more.
Mood modification	3. I play video games so I can forget about my problems. / I use social media apps so I can forget about my problems.
Loss of control	4. I've tried to play video games less but I can't. / I've tried to use my social media apps less but I can't.
Withdrawal	5. I've become stressed or upset if I am not allowed to play video games. / I've become stressed or upset if I am not allowed to use my social media apps.
Conflict	6. I play video games so much that it has had a bad effect on my schoolwork or job. / I use social media apps so much that it has had a bad effect on my schoolwork or job.
Mobile Phone Involvement Questionnaire	
Cognitive salience	1. I interrupt whatever else I am doing when I am contacted on my phone.
Behavioural salience	2. I often use my phone for no particular reason.
Euphoria	3. I feel connected to others when I am using my phone.
Conflict	4. Arguments have arisen with others because of my phone use.
Tolerance	5. I lose track of how much I am using my phone.
Preoccupation	6. I often think about my phone when I am not using it.
Loss of control	7. I have been unable to reduce my phone use.
Withdrawal	8. The thought of being without my phone makes me feel distressed.

Note. The dimensions of the problematic screen use scale used in this study were identified based on relevant literatures (Andreassen et al., 2012; Walsh et al., 2010).

3. Cross-sectional Networks Estimation

Following guidelines outlined in (Epskamp et al., 2018), a Gaussian graphical model (GGM) was constructed using the Extended Bayesian Information Criterion (EBIC) in combination with graphical lasso (gLASSO) algorithms. This approach leveraged penalty parameters to achieve sparsity and identify the optimal set of neighboring factors for each node. Edge thickness within the network corresponded to the partial correlation coefficient, denoting the strength of association between nodes while controlling for all other variables. Positive associations were depicted by green lines, while negative associations were represented by red. For enhanced clarity in visualizing sex-specific networks concurrently, an average layout technique was employed. Network estimation and visualization were conducted using the R package *qgraph* (Epskamp et al., 2012).

4. Cross-lagged Penal Networks (CLPNs) Estimation

CLPN models estimated autoregressive and cross-lagged coefficients. Autoregressive coefficients reflect the predictive power of a node at T2 on itself at T4, adjusted for all other nodes at T2. Cross-lagged coefficients indicate the predictive power of a node at T2 on a different node at T4, adjusted for all other nodes at T2. A LASSO-penalized maximum-likelihood procedure, with 10-fold cross-validation for tuning parameter selection, was applied to shrink small regression coefficients to zero. Arrows within the network represent estimates of effects, with edge thickness indicating the strength of association and color denoting directionality (blue for positive effects and red for negative effects). Regularized regressions were performed using the *glmnet* package (Friedman et al., 2010). Node placement was determined based on the average strength of sex-specific networks by *qgraph* package (Epskamp et al., 2012), with the algorithm positioning nodes closer together if they exhibited stronger connections.

5. Nonparametric Bootstrap Method

The nonparametric bootstrap method was utilized to assess the robustness and differences in node centrality and edge strength. Stability was quantified using the correlation stability coefficient (CS coefficient), measuring the maximum drop in proportions required to retain highly correlated ($r > 0.7$) network features. A CS coefficient higher than 0.5 indicates excellent network stability, while 0.5 to 0.25 indicates acceptable stability (Epskamp et al., 2018). Significant differences were determined when 1000-bootstrap 95% nonparametric confidence intervals did not encompass zero. The Network Comparison Test (NCT), which uses resampling-based permutation testing, was conducted to examine potential variations in characteristics between cross-sectional networks (van Borkulo et al., 2023). The packages *bootnet* (Epskamp & Fried, 2018) and *NetworkComparisonTest* (Van Borkulo, 2017) facilitated these analyses. Significant differences were determined when 1000-bootstrap 95% nonparametric confidence intervals did not encompass zero.

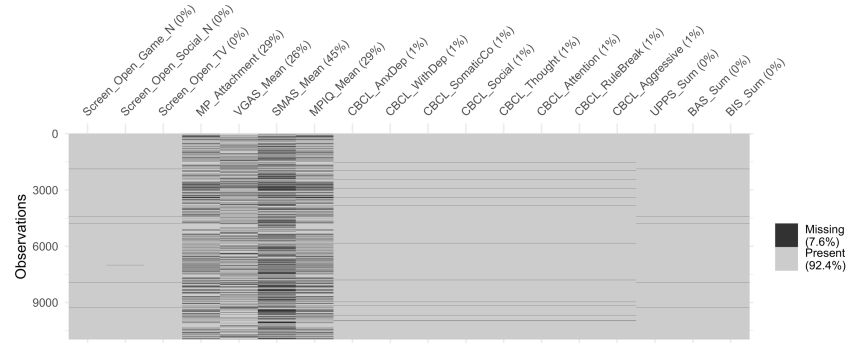
Supplemental Results

1. Description of variables

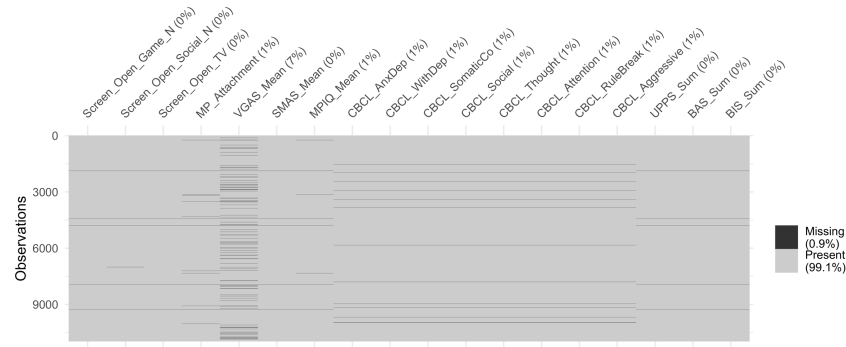
Little's MCAR test showed the remaining missing data after youth extraction was satisfied with random missingness (T2: $\chi^2 = 695.12$, $p < 0.001$; T4: $\chi^2 = 359.13$, $p < 0.001$).

eFigure 2. Missing Data of 2-year follow-up Cross-Sectional Network Analysis

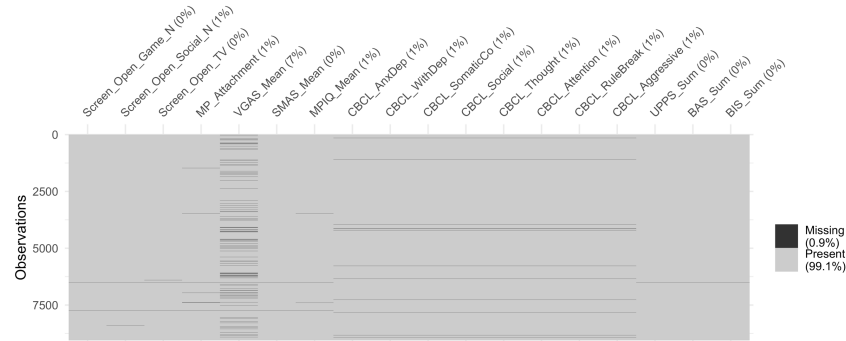
A. Missing percentage of raw valid data



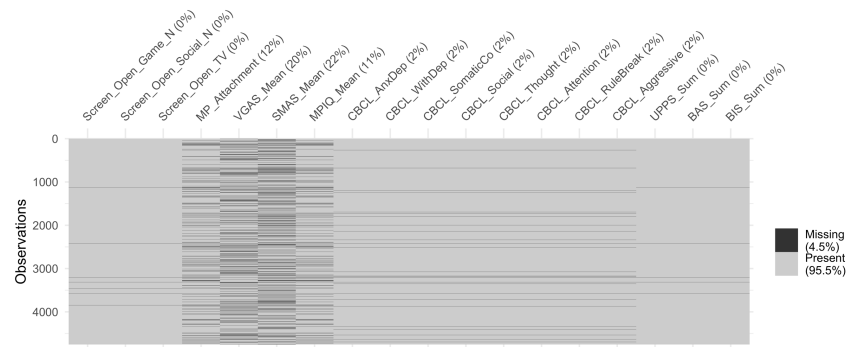
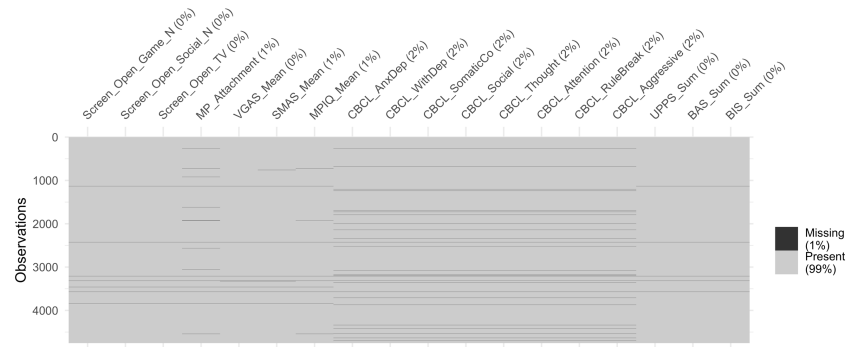
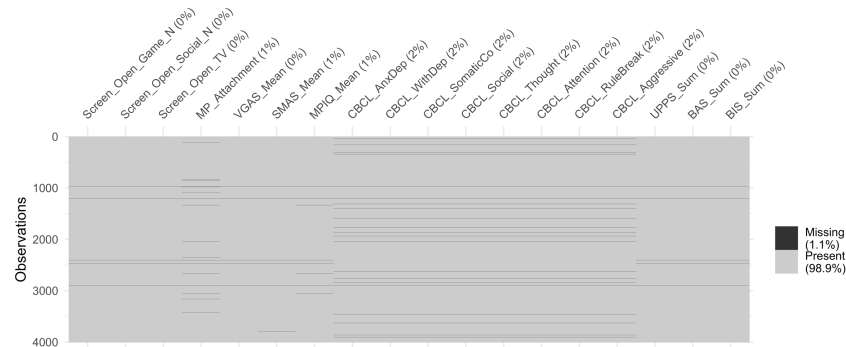
B. Missing percentage after minimum value imputation



C. Missing percentage after youth extraction



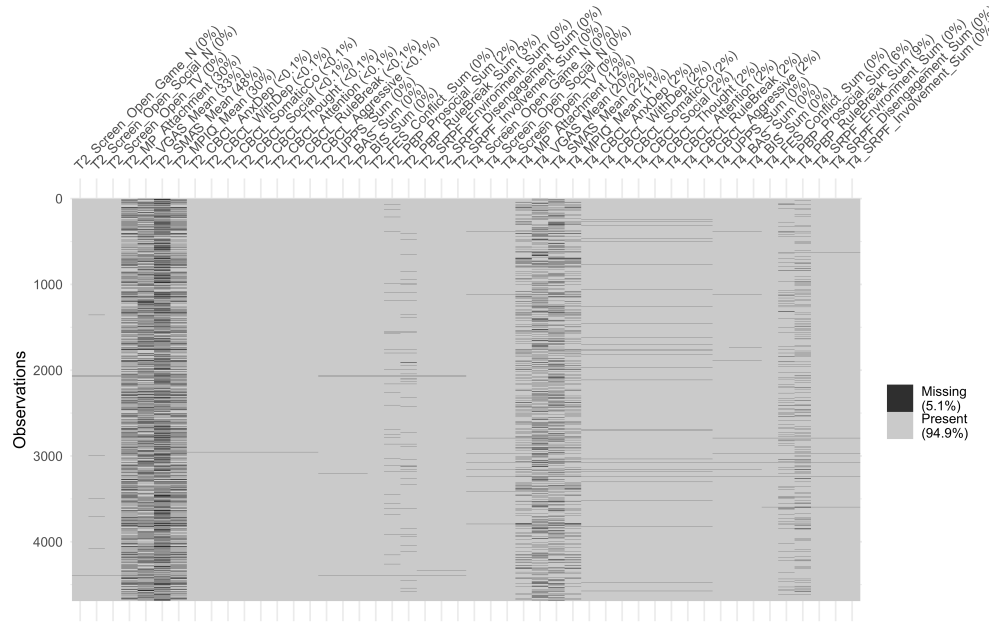
Note. For cross-sectional network analysis, participants who completed 2-year follow-up were included separately, and (A) the missing percentage of each variable is visualized. (B) Considering that some of the missing in VGAQ, SMAQ, and MPIQ were due to participants not meeting the prerequisites for using video games, having a social account, or owning a mobile device, these missing data were estimated using the minimum value of each scale. (C) To avoid the non-independence of the sample, an individual was randomly selected from a family with multiple youth participants.

eFigure 3. Missing Data of 4-year follow-up Cross-Sectional Network Analysis**A. Missing percentage of raw valid data****B. Missing percentage after minimum value imputation****C. Missing percentage after youth extraction**

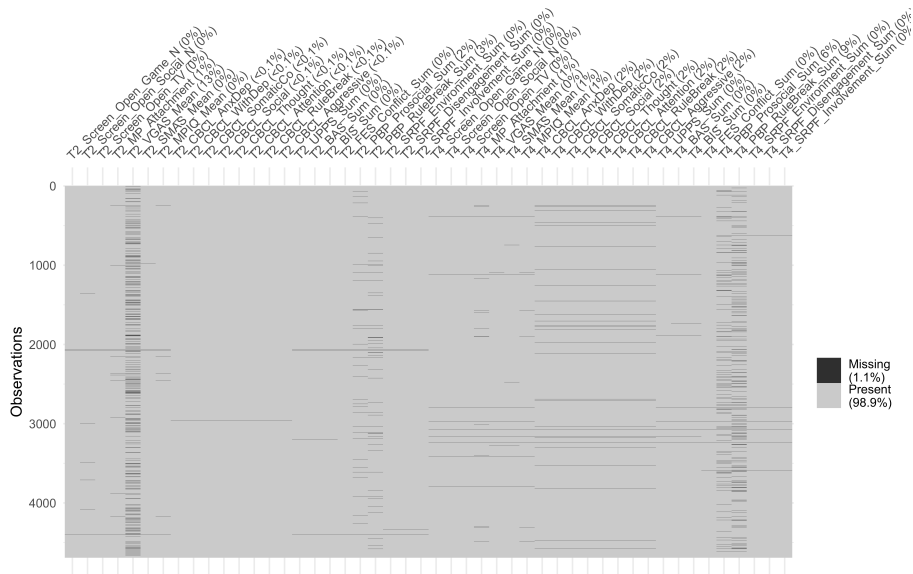
Note. For cross-sectional network analysis, participants who completed 4-year follow-up were included separately, and (A) the missing percentage of each variable is visualized. (B) Considering that some of the missing in VGAQ, SMAQ, and MPIQ were due to participants not meeting the prerequisites for using video games, having a social account, or owning a mobile device, these missing data were estimated using the minimum value of each scale. (C) To avoid the non-independence of the sample, an individual was randomly selected from a family with multiple youth participants.

eFigure 4. Missing Data of CLPN Analysis

A. Missing percentage of raw valid data



B. Missing percentage after minimum value imputation



Note. For CLPN, (A) participants who completed the 4-year follow-up with some missing data were included. (B) The missing data in VGAQ, SMAQ, and MPIQ related to not meeting the prerequisites were imputed by the minimum value of each scale.

eTable 5. Description of T2 Cross-Sectional Network Analysis Variables

	2-year-follow-up (n = 9,054)						
	Female (n = 4,272)			Male (n = 4,782)			p-value
	Range	No. (%) Mean (SD)	missing	Range	No. (%) Mean (SD)	missing	
video game use, No. (%)		2,826 (66%)	11		4,485 (94%)	18	<0.001
social media use, No. (%)		2,626 (62%)	13		2,407 (51%)	22	<0.001
own mobile phone, No. (%)		3,263 (77%)	17		3,276 (69%)	30	<0.001
Screen usage							
video game time	0.00, 23.75	1.23 (2.13)	11	0.00, 23.75	3.00 (3.29)	18	<0.001
social media time	0.00, 23.75	2.46 (3.68)	11	0.00, 23.75	1.40 (2.66)	18	<0.001
TV time	0.00, 23.75	1.46 (1.11)	11	0.00, 23.00	1.33 (1.12)	18	<0.001
checking behavior	1.00, 10.00	4.16 (2.78)	37	1.00, 10.00	3.58 (2.65)	42	<0.001
VGAS	1.00, 6.00	1.41 (0.74)	216	1.00, 6.00	2.31 (1.12)	397	<0.001
SMAS	1.00, 5.67	1.55 (0.86)	14	1.00, 6.00	1.42 (0.75)	24	<0.001
MPIQ	1.00, 7.00	2.68 (1.36)	17	1.00, 7.00	2.39 (1.30)	36	<0.001
CBCL							
anxious/depressed	50.00, 96.00	53.17 (5.79)	35	50.00, 91.00	53.34 (5.90)	30	0.174
withdrawn/depressed	50.00, 100.00	53.40 (5.90)	35	50.00, 100.00	53.90 (6.06)	30	<0.001
somatic complaints	50.00, 82.00	54.72 (5.86)	35	50.00, 88.00	54.60 (5.98)	30	0.357
social problems	50.00, 89.00	52.47 (4.65)	35	50.00, 88.00	52.84 (4.99)	30	<0.001
thought problems	50.00, 83.00	53.62 (5.72)	35	50.00, 89.00	53.92 (6.00)	30	0.014
attention problems	50.00, 97.00	53.52 (5.70)	35	50.00, 96.00	53.78 (5.76)	30	0.032
rule-breaking behavior	50.00, 80.00	52.02 (4.05)	35	50.00, 84.00	52.22 (4.24)	30	0.021
aggressive behavior	50.00, 93.00	52.05 (4.50)	35	50.00, 95.00	52.68 (5.27)	30	<0.001
Behavioral Tendencies							
UPPS	20.00, 77.00	38.51 (7.88)	11	20.00, 70.00	40.54 (7.51)	19	<0.001
BAS	0.00, 36.00	15.81 (6.20)	11	0.00, 36.00	16.71 (6.33)	19	<0.001
BIS	0.00, 12.00	5.46 (2.88)	11	0.00, 12.00	4.54 (2.70)	19	<0.001

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eTable 6. Description of T4 Cross-Sectional Network Analysis Variables

	4-year-follow-up (n = 4,007)						
	Female (n = 1,896)			Male (n = 2,111)			<i>p</i> -value
	Range	Mean (SD)	missing	Range	Mean (SD)	missing	
video game use, No. (%)		1,215 (64%)	3		1,984 (95%)	14	<0.001
social media use, No. (%)		1,572 (83%)	3		1,590 (76%)	14	<0.001
own mobile phone, No. (%)		1,724 (91%)	5		1,849 (88%)	16	0.003
Screen usage							
video game time	0.00, 23.75	1.75 (2.80)	3	0.00, 23.75	4.10 (3.82)	14	<0.001
social media time	0.00, 23.75	4.73 (4.64)	3	0.00, 23.75	3.28 (4.12)	14	<0.001
TV time	0.00, 22.71	3.14 (2.53)	3	0.00, 23.75	3.16 (2.55)	14	0.787
checking behavior	1.00, 10.00	5.43 (2.58)	14	1.00, 10.00	4.63 (2.56)	28	<0.001
VGAS	1.00, 5.50	1.53 (0.88)	3	1.00, 6.00	2.31 (1.06)	16	<0.001
SMAS	1.00, 5.67	1.96 (0.99)	3	1.00, 6.00	1.62 (0.84)	19	<0.001
MPIQ	1.00, 6.75	3.34 (1.27)	5	1.00, 7.00	2.88 (1.21)	18	<0.001
CBCL							
anxious/depressed	50.00, 92.00	53.61 (6.36)	37	50.00, 91.00	52.74 (5.51)	32	<0.001
withdrawn/depressed	50.00, 100.00	54.22 (6.93)	37	50.00, 89.00	53.72 (5.65)	32	0.013
somatic complaints	50.00, 86.00	54.79 (6.30)	37	50.00, 85.00	54.03 (5.65)	32	<0.001
social problems	50.00, 82.00	52.35 (4.61)	37	50.00, 84.00	52.23 (4.55)	32	0.411
thought problems	50.00, 81.00	54.00 (6.10)	37	50.00, 82.00	53.30 (5.53)	32	<0.001
attention problems	50.00, 87.00	53.60 (5.78)	37	50.00, 81.00	53.17 (5.06)	32	0.013
rule-breaking behavior	50.00, 77.00	51.82 (3.86)	37	50.00, 81.00	51.81 (3.64)	32	0.935
aggressive behavior	50.00, 83.00	51.73 (4.06)	37	50.00, 86.00	52.09 (4.57)	32	0.008
Behavioral Tendencies							
UPPS	20.00, 70.00	41.21 (8.23)	3	21.00, 77.00	41.79 (7.41)	13	0.018
BAS	0.00, 36.00	16.38 (5.99)	4	0.00, 36.00	16.53 (6.12)	13	0.427
BIS	0.00, 12.00	6.34 (2.95)	4	0.00, 12.00	4.70 (2.73)	13	<0.001

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

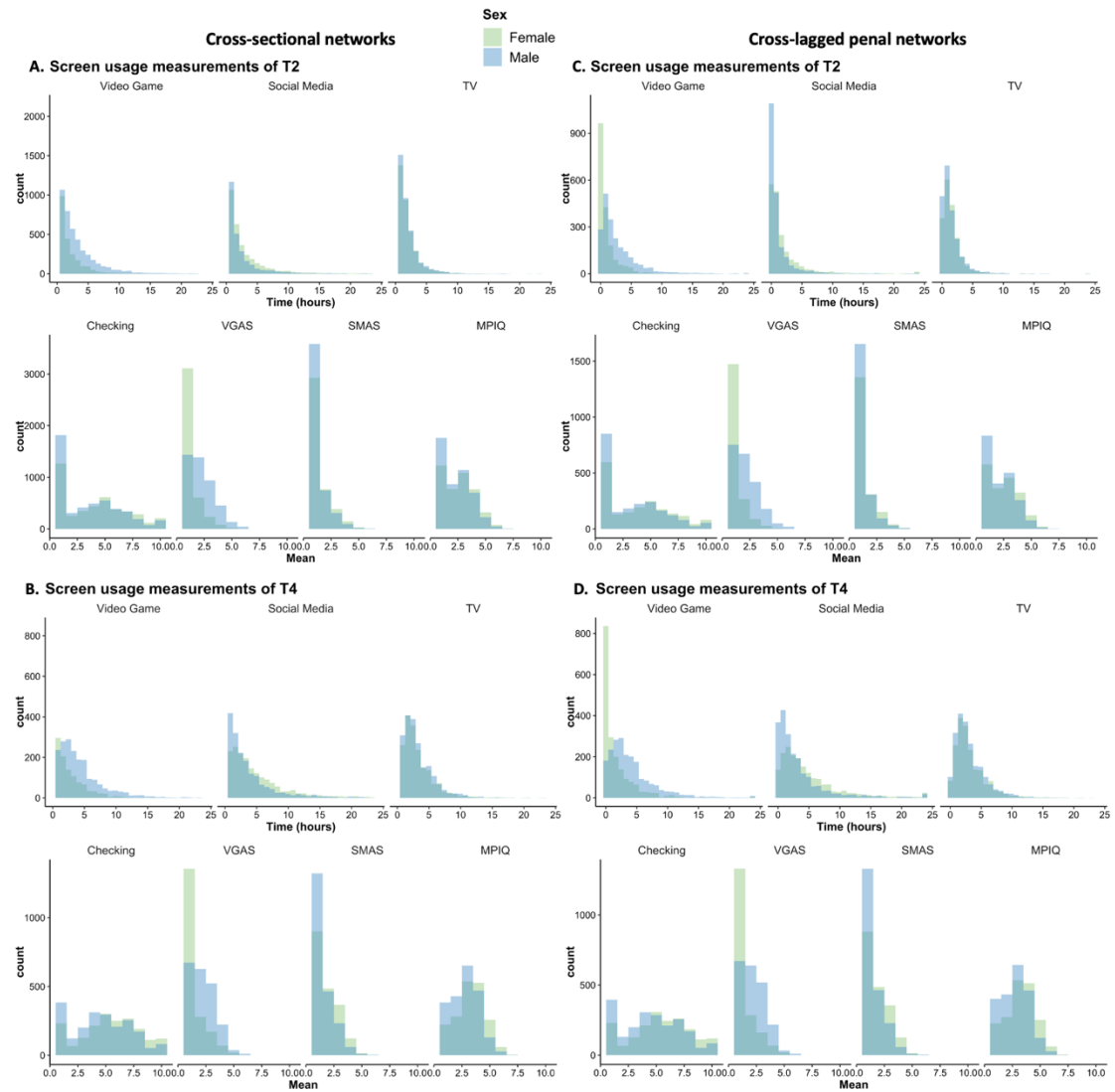
eTable 7. Description of CLPN Analysis Variables

	2-year-follow-up (n = 3,954)					4-year-follow-up (n = 3,954)				
	Female (n = 1,863)		Male (n = 2,091)		<i>p</i> -value	Female (n = 1,863)		Male (n = 2,091)		<i>p</i> -value
	Range	Mean (SD)	Range	Mean (SD)		Range	Mean (SD)	Range	Mean (SD)	
video game use, No. (%)		1,197 (64%)		1,959 (94%)	<0.001		1,192 (64%)		1,962 (94%)	<0.001
social media use, No. (%)		1,092 (59%)		983 (47%)	<0.001		1,552 (83%)		1,569 (76%)	<0.001
own mobile phone, No. (%)		1,408 (76%)		1,398 (67%)	<0.001		1,695 (91%)		1,818 (88%)	<0.001
Screen usage										
video game time	0.00, 23.75	1.07 (1.99)	0.00, 23.75	2.82 (3.14)	<0.001	0.00, 23.75	1.78 (2.88)	0.00, 23.75	4.06 (3.74)	<0.001
social media time	0.00, 23.75	2.00 (3.32)	0.00, 23.75	1.12 (2.34)	<0.001	0.00, 23.75	4.80 (4.72)	0.00, 23.75	3.24 (4.10)	<0.001
TV time	0.00, 23.36	1.55 (1.60)	0.00, 23.39	1.46 (1.68)	0.122	0.00, 22.71	3.18 (2.58)	0.00, 21.07	3.13 (2.47)	0.568
checking behavior	1.00, 10.00	4.00 (2.76)	1.00, 10.00	3.36 (2.53)	<0.001	1.00, 10.00	5.42 (2.58)	1.00, 10.00	4.60 (2.58)	<0.001
VGAS	1.00, 6.00	1.35 (0.67)	1.00, 6.00	2.21 (1.08)	<0.001	1.00, 5.50	1.53 (0.88)	1.00, 6.00	2.29 (1.05)	<0.001
SMAS	1.00, 5.33	1.46 (0.77)	1.00, 5.50	1.34 (0.66)	<0.001	1.00, 5.67	1.96 (0.99)	1.00, 6.00	1.62 (0.83)	<0.001
MPIQ	1.00, 7.00	2.58 (1.32)	1.00, 7.00	2.27 (1.24)	<0.001	1.00, 6.75	3.34 (1.28)	1.00, 6.63	2.85 (1.21)	<0.001
CBCL										
anxious/depressed	50.00, 90.00	53.26 (5.74)	50.00, 90.00	53.29 (5.80)	0.846	50.00, 92.00	53.62 (6.35)	50.00, 91.00	52.73 (5.46)	<0.001
withdrawn/depressed	50.00, 100.00	53.18 (5.45)	50.00, 93.00	53.84 (5.77)	<0.001	50.00, 100.00	54.26 (6.95)	50.00, 89.00	53.71 (5.68)	0.007
somatic complaints	50.00, 84.00	54.79 (6.02)	50.00, 88.00	54.69 (5.82)	0.599	50.00, 84.00	54.73 (6.22)	50.00, 85.00	54.07 (5.63)	<0.001
social problems	50.00, 89.00	52.39 (4.59)	50.00, 83.00	52.71 (4.77)	0.033	50.00, 82.00	52.37 (4.62)	50.00, 84.00	52.19 (4.55)	0.211
thought problems	50.00, 81.00	53.48 (5.51)	50.00, 82.00	53.94 (5.83)	0.010	50.00, 81.00	53.97 (6.07)	50.00, 82.00	53.27 (5.49)	<0.001
attention problems	50.00, 90.00	53.28 (5.32)	50.00, 96.00	53.74 (5.65)	0.008	50.00, 87.00	53.67 (5.85)	50.00, 90.00	53.18 (5.11)	0.005
rule-breaking behavior	50.00, 76.00	52.08 (4.11)	50.00, 81.00	52.11 (3.96)	0.804	50.00, 77.00	51.88 (3.96)	50.00, 81.00	51.83 (3.65)	0.652

aggressive behavior	50.00, 85.00	52.01 (4.40)	50.00, 89.00	52.52 (4.86)	<0.001	50.00, 83.00	51.80 (4.24)	50.00, 83.00	52.06 (4.47)	0.053
Behavioral Tendencies										
UPPS	20.00, 77.00	37.92 (8.02)	20.00, 68.00	40.16 (7.60)	<0.001	20.00, 70.00	41.19 (8.26)	21.00, 77.00	41.78 (7.47)	0.019
BAS	0.00, 36.00	15.82 (6.33)	0.00, 36.00	16.76 (6.30)	<0.001	0.00, 36.00	16.32 (6.09)	0.00, 36.00	16.50 (6.09)	0.372
BIS	0.00, 12.00	5.54 (2.89)	0.00, 12.00	4.62 (2.67)	<0.001	0.00, 12.00	6.34 (2.98)	0.00, 12.00	4.72 (2.73)	<0.001
Environmental Factor										
Family Conflict	0.00, 9.00	1.77 (1.80)	0.00, 9.00	1.86 (1.80)	0.136	0.00, 9.00	2.29 (2.14)	0.00, 9.00	2.09 (2.00)	0.003
Prosocial Peers (RE)	2.00, 15.00	9.39 (2.61)	2.00, 15.00	9.31 (2.58)	0.329	2.00, 15.00	8.61 (2.86)	2.00, 15.00	8.65 (2.78)	0.637
Rule-Breaking Peers	2.00, 11.00	3.50 (1.06)	2.00, 15.00	3.71 (1.31)	<0.001	2.00, 15.00	3.78 (1.54)	2.00, 15.00	3.87 (1.62)	0.074
School Disengagement	2.00, 8.00	3.79 (1.31)	2.00, 8.00	4.06 (1.34)	<0.001	2.00, 8.00	4.41 (1.31)	2.00, 8.00	4.60 (1.35)	<0.001
School Involvement (RE)	6.00, 24.00	19.71 (2.79)	9.00, 24.00	19.37 (2.81)	<0.001	6.00, 24.00	18.87 (2.75)	7.00, 24.00	18.93 (2.79)	0.474
School Environment (RE)	4.00, 16.00	12.90 (2.38)	4.00, 16.00	12.51 (2.30)	<0.001	4.00, 16.00	12.10 (2.40)	4.00, 16.00	12.13 (2.17)	0.708

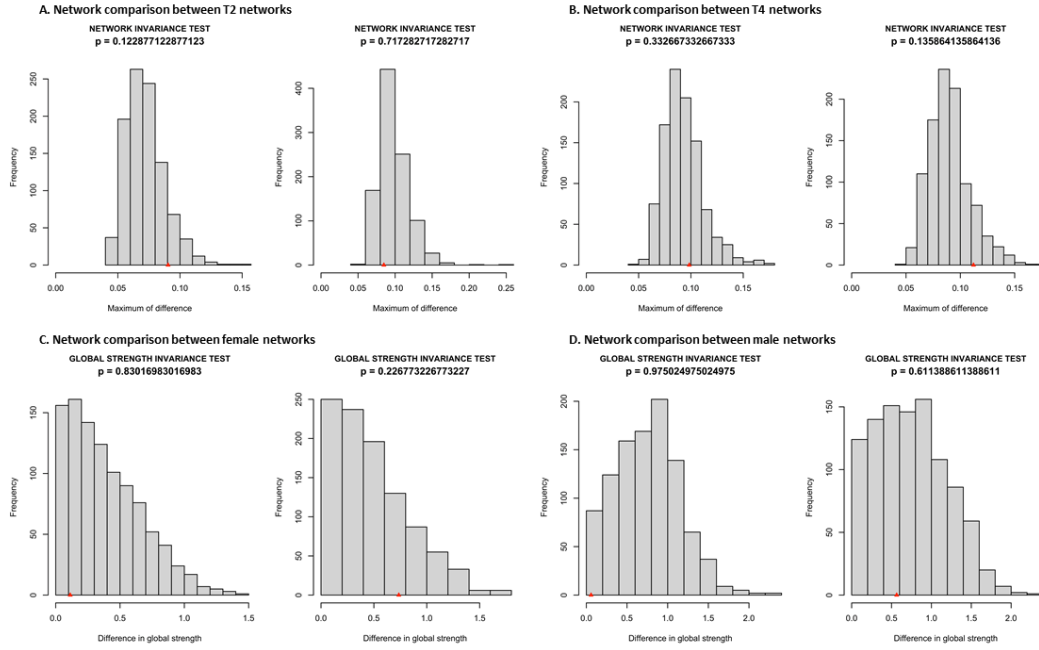
Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eFigure 5. Data Distribution of Screen Usage Measurements



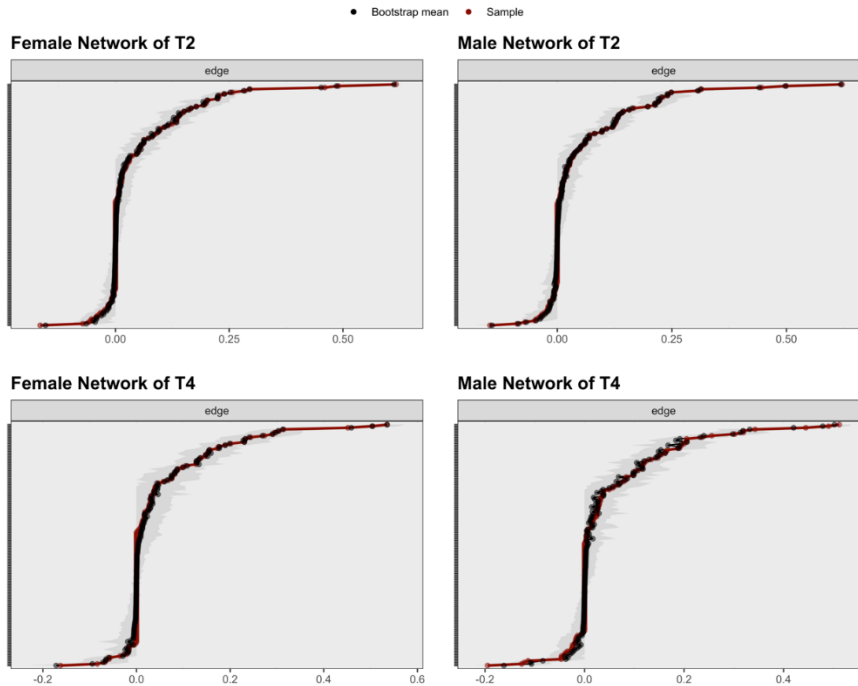
2. Cross-sectional Networks

eFigure 6. Network comparison of cross-sectional networks

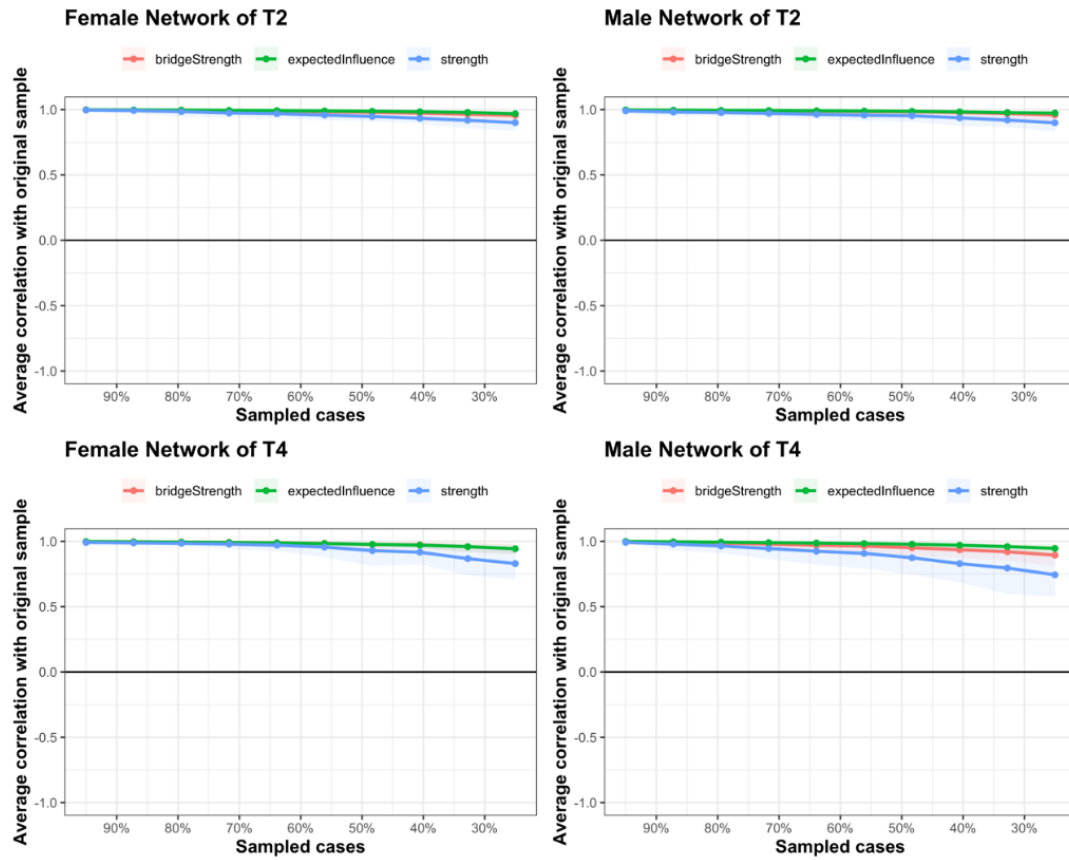


Note. The Network Comparison Test was conducted to examine network structure and global strength (A, B) between sex-specific networks at the same time point and (C, D) between T2 and T4 networks of the same sex. The red triangle marks the position of the indicator of the current networks among all the indicators obtained in the resampling permutation test.

eFigure 7. Bootstrapped Edge-Weight Accuracy Test of Cross-Sectional Networks



Note. Gray areas reflect bootstrapped 95% confidence intervals of the edge weights for networks.

eFigure 8. Case-Dropping Bootstrapped Centrality Indices for Cross-Sectional Networks

Note. Lines reflect mean correlations between centrality values of the original sample and sub-samples with different degrees of persons dropped, and areas around the lines reflect 95% CIs.

eTable 8. Top 10 Edges of Cross-Sectional Networks Based on Bootstrapping

Index	Node1	Node2	Mean strength	Community of node1	Community of node2
Female network of T2					
1	B3	A3	0.612	Screen Usage	Screen Usage
2	C7	C8	0.486	Psychopathology	Psychopathology
3	B1	A1	0.452	Screen Usage	Screen Usage
4	C1	C2	0.294	Psychopathology	Psychopathology
5	C5	C6	0.282	Psychopathology	Psychopathology
6	B2	A2	0.253	Screen Usage	Screen Usage
7	A2	A3	0.239	Screen Usage	Screen Usage
8	BIS	BAS	0.225	Behavior Tendencies	Behavior Tendencies
9	C4	C6	0.224	Psychopathology	Psychopathology
10	A1	UPPS	0.224	Screen Usage	Behavior Tendencies
Female network of T2: Screen Usage – other nodes					
10	A1	UPPS	0.224	Screen Usage	Behavior Tendencies
26	A3	UPPS	0.126	Screen Usage	Behavior Tendencies
32	A2	UPPS	0.094	Screen Usage	Behavior Tendencies
34	A2	BIS	0.080	Screen Usage	Behavior Tendencies
37	B1	BIS	-0.064	Screen Usage	Behavior Tendencies
39	A1	BAS	0.062	Screen Usage	Behavior Tendencies
43	A2	BAS	0.054	Screen Usage	Behavior Tendencies
45	A3	BIS	0.050	Screen Usage	Behavior Tendencies
47	B2	C7	0.047	Screen Usage	Psychopathology
50	B3	UPPS	-0.041	Screen Usage	Behavior Tendencies
Male network of T2					
1	B3	A3	0.619	Screen Usage	Screen Usage
2	C7	C8	0.498	Psychopathology	Psychopathology
3	B1	A1	0.441	Screen Usage	Screen Usage
4	C5	C6	0.313	Psychopathology	Psychopathology
5	C1	C2	0.306	Psychopathology	Psychopathology
6	A2	A3	0.249	Screen Usage	Screen Usage
7	BIS	BAS	0.240	Behavior Tendencies	Behavior Tendencies
8	B2	B4	0.240	Screen Usage	Screen Usage
9	B1	B4	0.227	Screen Usage	Screen Usage
10	C4	C8	0.223	Psychopathology	Psychopathology
Male network of T2: Screen Usage – other nodes					
13	A1	UPPS	0.214	Screen Usage	Behavior Tendencies
29	A3	UPPS	0.119	Screen Usage	Behavior Tendencies
32	A2	UPPS	0.0966	Screen Usage	Behavior Tendencies
33	B1	BIS	-0.085	Screen Usage	Behavior Tendencies
36	A2	BIS	0.069	Screen Usage	Behavior Tendencies

40	A1	BAS	0.062	Screen Usage	Behavior Tendencies
41	A2	BAS	0.060	Screen Usage	Behavior Tendencies
44	A3	BIS	0.050	Screen Usage	Behavior Tendencies
46	A1	BIS	0.046	Screen Usage	Behavior Tendencies
52	B2	C7	0.033	Screen Usage	Psychopathology
Female network of T4					
1	B3	A3	0.536	Screen Usage	Screen Usage
2	C7	C8	0.503	Psychopathology	Psychopathology
3	B1	A1	0.459	Screen Usage	Screen Usage
4	A2	A3	0.312	Screen Usage	Screen Usage
5	C5	C6	0.303	Psychopathology	Psychopathology
6	B1	B4	0.297	Screen Usage	Screen Usage
7	C1	C2	0.290	Psychopathology	Psychopathology
8	C4	C8	0.269	Psychopathology	Psychopathology
9	C1	C4	0.241	Psychopathology	Psychopathology
10	B2	A2	0.232	Screen Usage	Screen Usage
Female network of T4: Screen Usage – other nodes					
15	A1	UPPS	0.177	Screen Usage	Behavior Tendencies
21	A3	UPPS	0.152	Screen Usage	Behavior Tendencies
26	A2	UPPS	0.129	Screen Usage	Behavior Tendencies
29	A2	BIS	0.100	Screen Usage	Behavior Tendencies
34	A3	BIS	0.081	Screen Usage	Behavior Tendencies
41	B3	UPPS	-0.065	Screen Usage	Behavior Tendencies
42	A1	C2	0.060	Screen Usage	Psychopathology
43	B1	BIS	-0.060	Screen Usage	Behavior Tendencies
44	B2	C7	0.047	Screen Usage	Psychopathology
51	B3	BAS	0.037	Screen Usage	Behavior Tendencies
Male network of T4					
1	B3	A3	0.502	Screen Usage	Screen Usage
2	C7	C8	0.479	Psychopathology	Psychopathology
3	B1	A1	0.42	Screen Usage	Screen Usage
4	B1	B4	0.332	Screen Usage	Screen Usage
5	A2	A3	0.318	Screen Usage	Screen Usage
6	C1	C2	0.313	Psychopathology	Psychopathology
7	C5	C6	0.298	Psychopathology	Psychopathology
8	B2	A2	0.24	Screen Usage	Screen Usage
9	C1	C4	0.233	Psychopathology	Psychopathology
10	B2	B4	0.206	Screen Usage	Screen Usage
Male network of T4: Screen Usage – other nodes					
23	A1	UPPS	0.142	Screen Usage	Behavior Tendencies
27	A2	UPPS	0.116	Screen Usage	Behavior Tendencies

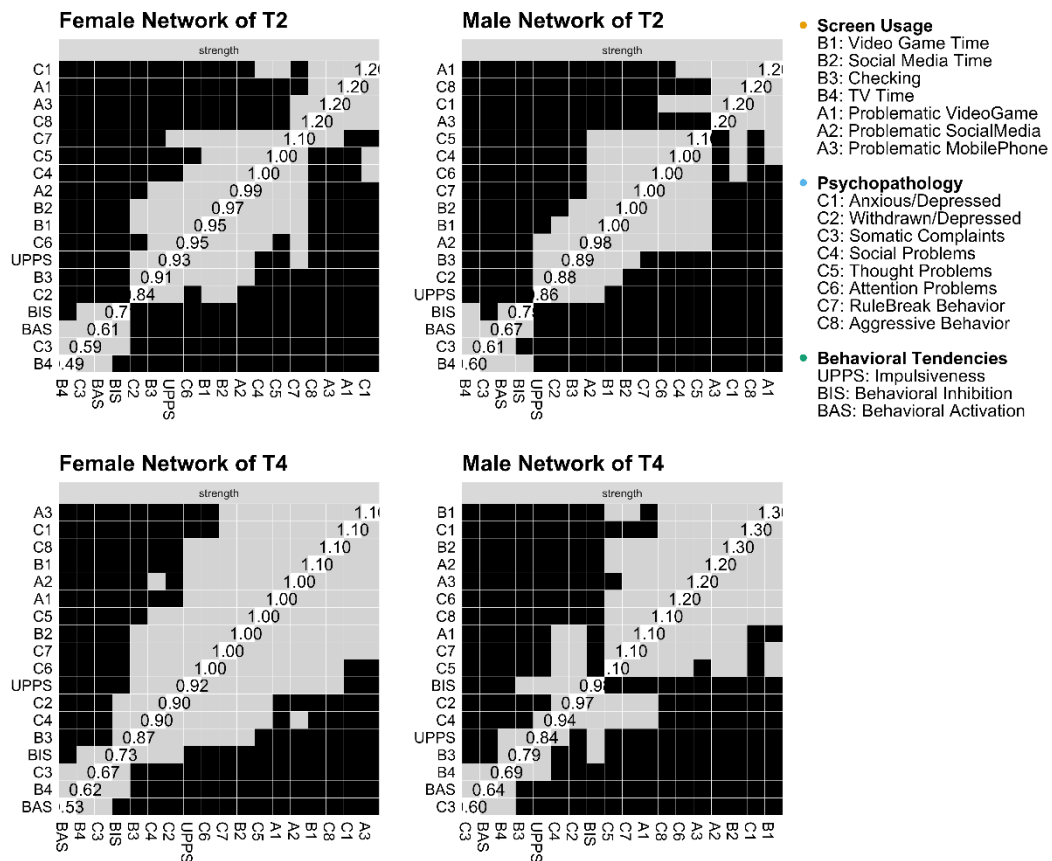
28	A3	BIS	0.114	Screen Usage	Behavior Tendencies
29	B1	BIS	-0.108	Screen Usage	Behavior Tendencies
35	A3	UPPS	0.0980	Screen Usage	Behavior Tendencies
36	A2	BIS	0.097	Screen Usage	Behavior Tendencies
45	B2	UPPS	0.050	Screen Usage	Behavior Tendencies
46	B3	C8	-0.040	Screen Usage	Psychopathology
50	B2	C7	0.037	Screen Usage	Psychopathology
56	B3	BAS	0.027	Screen Usage	Behavior Tendencies

eTable 9. Comparison of Node Centrality Differences Between Cross-Sectional Networks

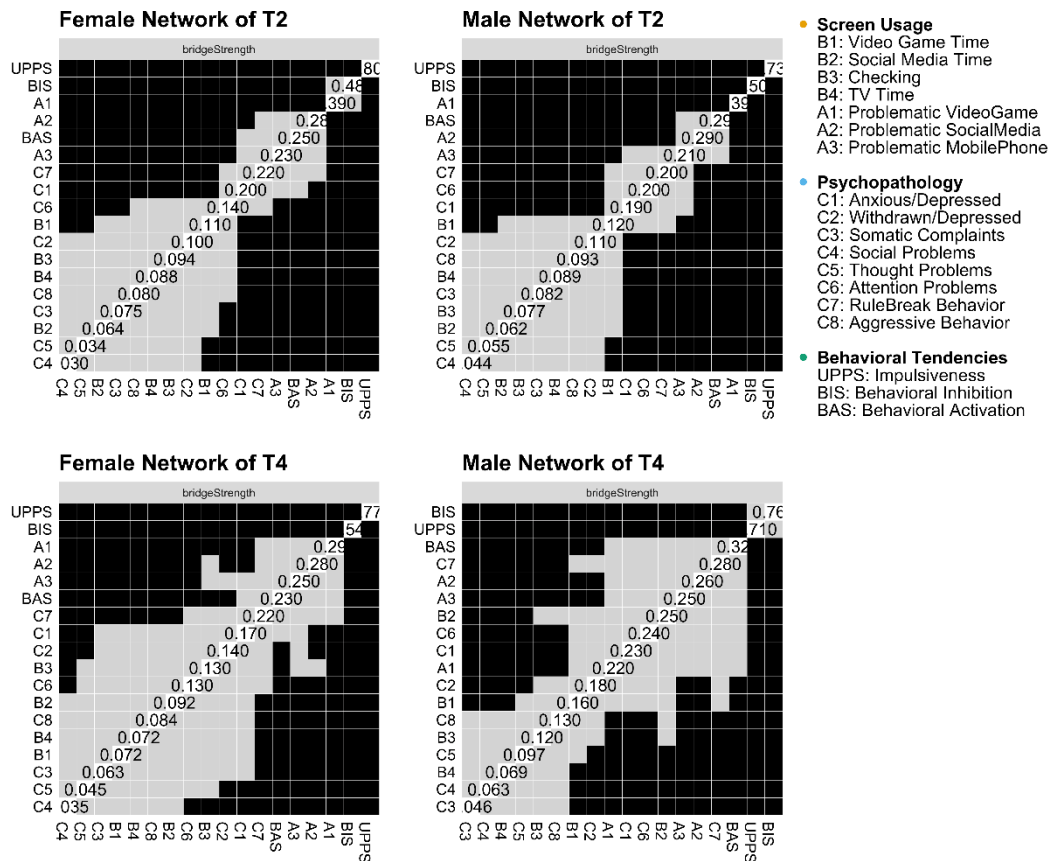
Node	Strength	<i>p</i> -values of strength	EI	<i>p</i> - values of EI	Node	Strength	<i>p</i> -values of strength	EI	<i>p</i> -values of EI
T2: Female network vs. Male network					T4: Female network vs. Male network				
B1	-0.056	0.597	0.001	0.995	B1	-0.202	0.148	-0.007	0.907
B2	-0.037	0.680	-0.059	0.265	B2	-0.240	0.119	-0.003	0.973
B3	0.021	0.750	0.000	1.000	B3	0.079	0.420	0.044	0.463
B4	-0.113	0.228	-0.101	0.049	B4	-0.066	0.378	-0.017	0.782
A1	0.012	0.917	0.029	0.530	A1	-0.082	0.537	0.028	0.694
A2	0.016	0.867	0.067	0.151	A2	-0.149	0.141	-0.030	0.650
A3	0.011	0.876	-0.006	0.889	A3	-0.035	0.641	-0.065	0.286
C1	0.061	0.567	0.015	0.756	C1	-0.141	0.157	-0.027	0.686
C2	-0.037	0.477	-0.012	0.792	C2	-0.068	0.360	0.018	0.808
C3	-0.021	0.735	-0.012	0.767	C3	0.072	0.251	0.072	0.221
C4	-0.002	0.972	-0.003	0.953	C4	-0.034	0.618	-0.021	0.737
C5	-0.018	0.702	-0.032	0.437	C5	-0.045	0.547	0.064	0.295
C6	-0.080	0.076	-0.015	0.698	C6	-0.155	0.041	-0.036	0.608
C7	0.050	0.631	0.005	0.910	C7	-0.109	0.281	-0.099	0.172
C8	-0.012	0.853	0.013	0.762	C8	-0.016	0.832	0.101	0.142
UPPS	0.073	0.455	-0.029	0.480	UPPS	0.077	0.552	0.013	0.835
BIS	-0.037	0.695	0.012	0.777	BIS	-0.255	0.089	-0.028	0.613
BAS	-0.058	0.425	-0.020	0.617	BAS	-0.105	0.292	0.015	0.822
Female network: T2 vs. T4					Male network: T2 vs. T4				
B1	-0.120	0.576	-0.004	0.952	B1	-0.266	0.121	-0.011	0.875
B2	-0.048	0.815	-0.054	0.449	B2	-0.251	0.143	0.002	0.985
B3	0.049	0.737	0.109	0.025	B3	0.107	0.237	0.153	0.001
B4	-0.136	0.184	-0.235	0.001	B4	-0.089	0.480	-0.151	0.019
A1	0.176	0.447	0.092	0.183	A1	0.083	0.781	0.092	0.129
A2	-0.053	0.700	-0.025	0.646	A2	-0.218	0.097	-0.122	0.034
A3	0.020	0.842	0.021	0.784	A3	-0.027	0.707	-0.037	0.584
C1	0.094	0.653	-0.086	0.103	C1	-0.108	0.478	-0.129	0.032

C2	-0.061	0.417	-0.009	0.874	C2	-0.091	0.260	0.020	0.706
C3	-0.082	0.216	-0.128	0.020	C3	0.010	0.880	-0.045	0.354
C4	0.132	0.037	0.151	0.013	C4	0.100	0.165	0.133	0.017
C5	0.012	0.843	-0.024	0.632	C5	-0.014	0.822	0.072	0.160
C6	-0.052	0.378	-0.075	0.173	C6	-0.127	0.056	-0.096	0.080
C7	0.073	0.721	-0.008	0.894	C7	-0.086	0.577	-0.112	0.066
C8	0.036	0.707	0.038	0.503	C8	0.032	0.716	0.126	0.026
UPPS	0.014	0.963	-0.023	0.600	UPPS	0.018	0.896	0.019	0.671
BIS	-0.017	0.944	0.008	0.894	BIS	-0.235	0.196	-0.032	0.611
BAS	0.079	0.531	0.101	0.074	BAS	0.033	0.807	0.136	0.014

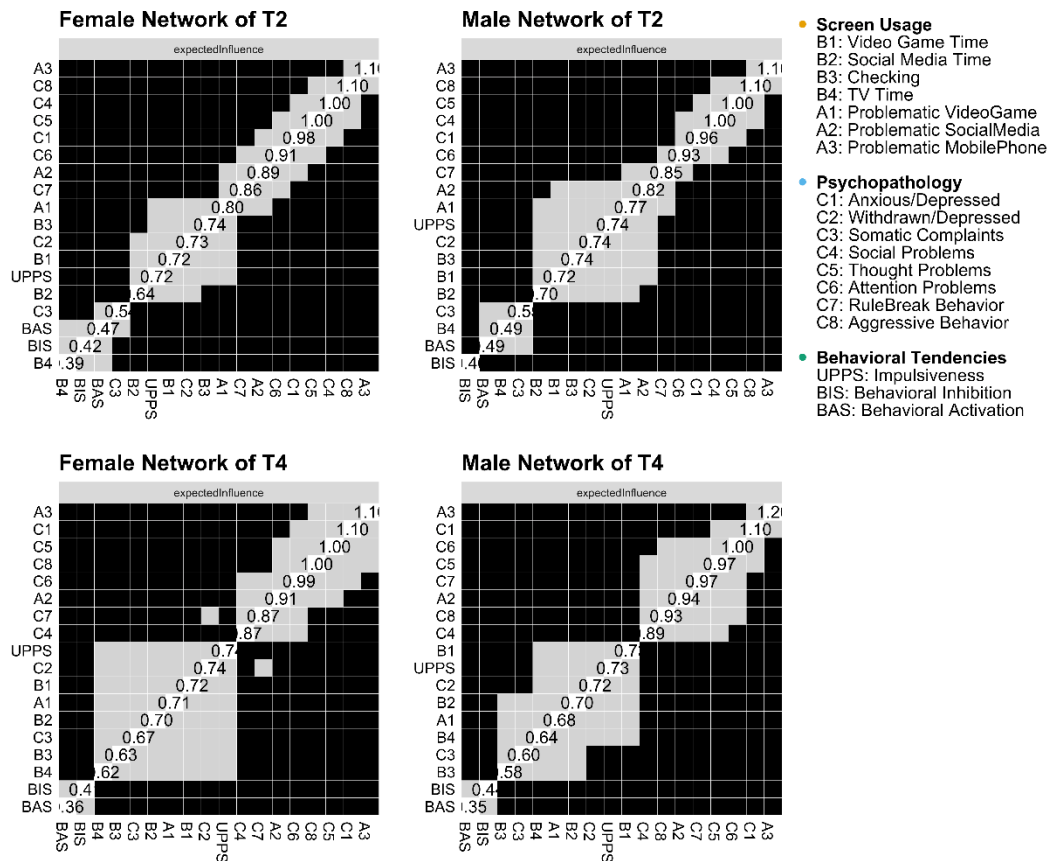
eFigure 9. Difference Test of Strength in Cross-Sectional Networks



Note. Nonparametric bootstrapped difference test for strength provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

eFigure 10. Difference Test of EI in Cross-Sectional Networks

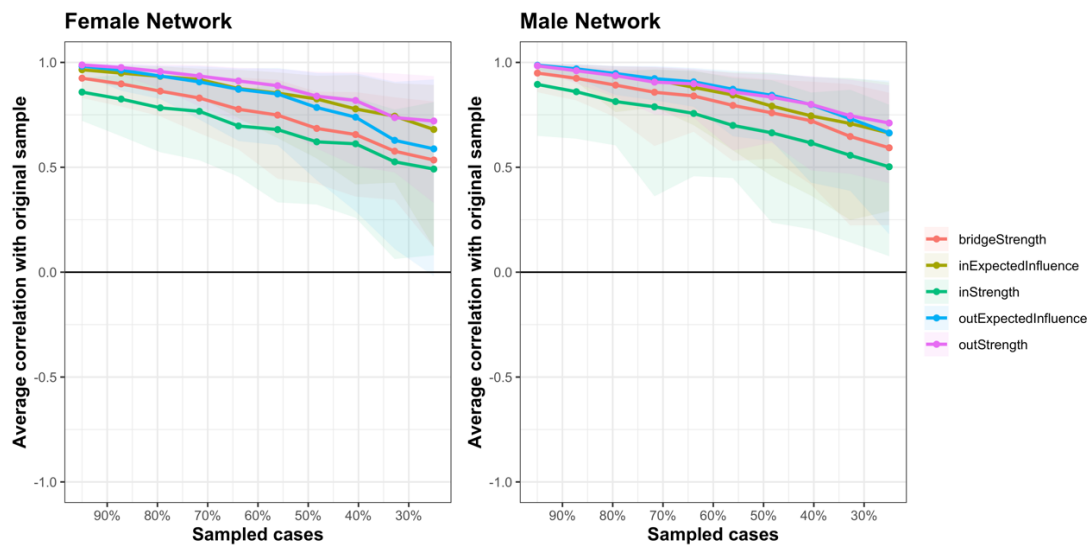
Note. Nonparametric bootstrapped difference test for EI provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

eFigure 11. Difference Test of Bridge Strength in Cross-Sectional Networks

Note. Nonparametric bootstrapped difference test for bridge strength provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

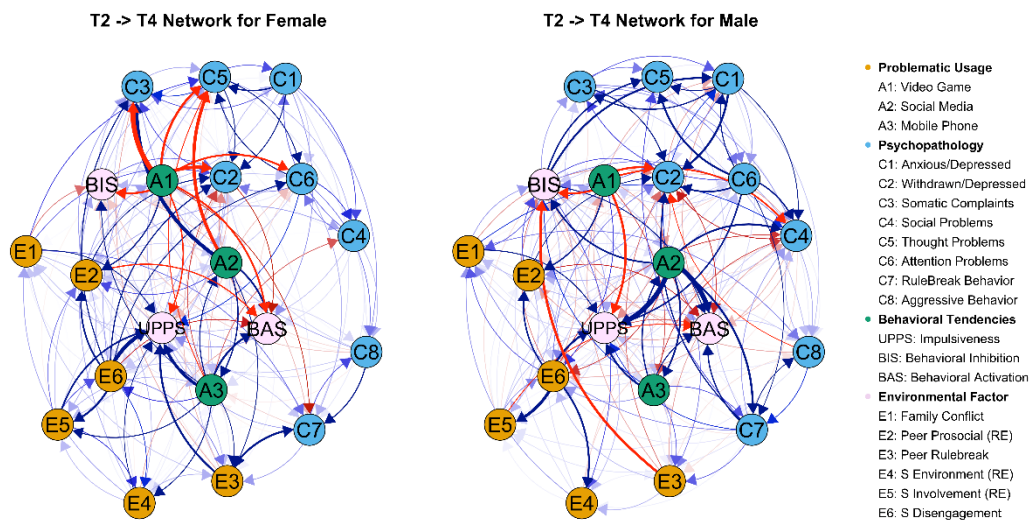
3. Cross-lagged Penal Networks (CLPNs)

eFigure 12. Case-Dropping Bootstrapped Centrality Indices for CLPNs



Note. The correlation stability analysis showed the acceptable stability of networks. out-strength: 0.516, in-strength: 0.05, in-EI: 0.361, out-EI: 0.439, bridge strength: 0.361.

eFigure 13. CLPNs Without Thresholds



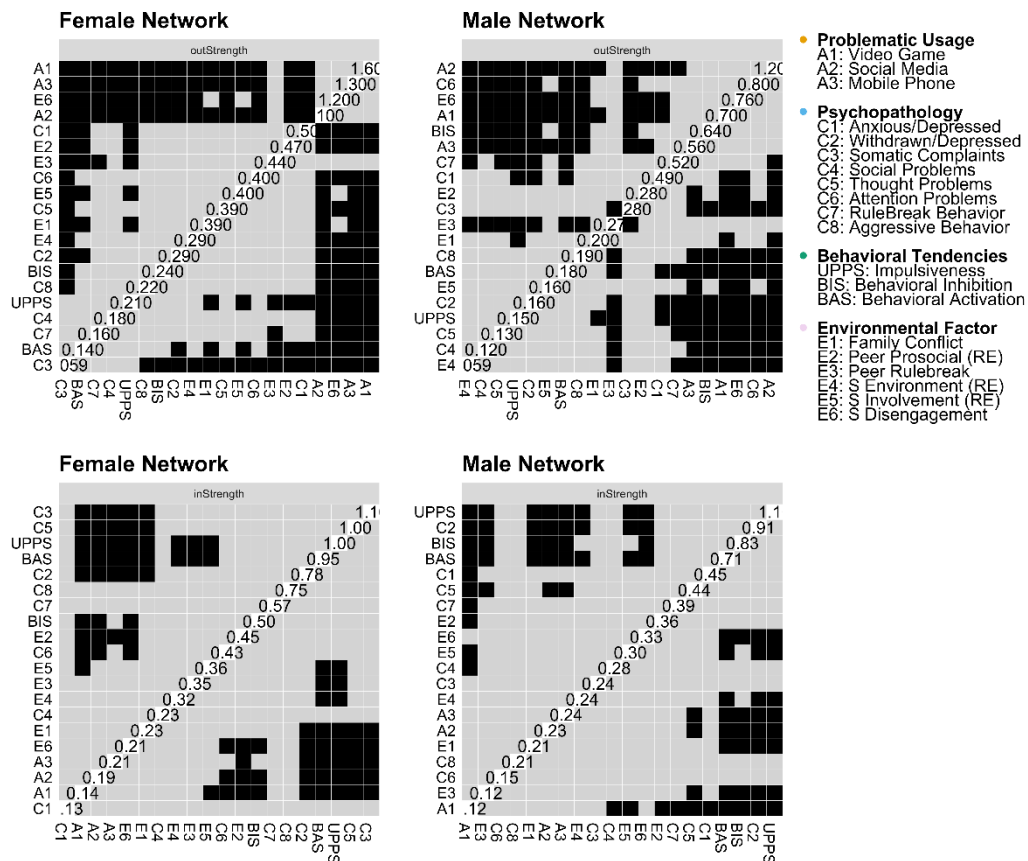
Note. In the networks, the arrow of the edge represents the direction of the association, the thickness represents the strength of the association, and the color represents the positive (blue) or negative (red) of the association. The weaker edges were included in the plot, while autoregressive edges and covariates were excluded from the plot to ease visual interpretation.

eTable 10. Top 10 Edges of CLPNs Based on Bootstrapping

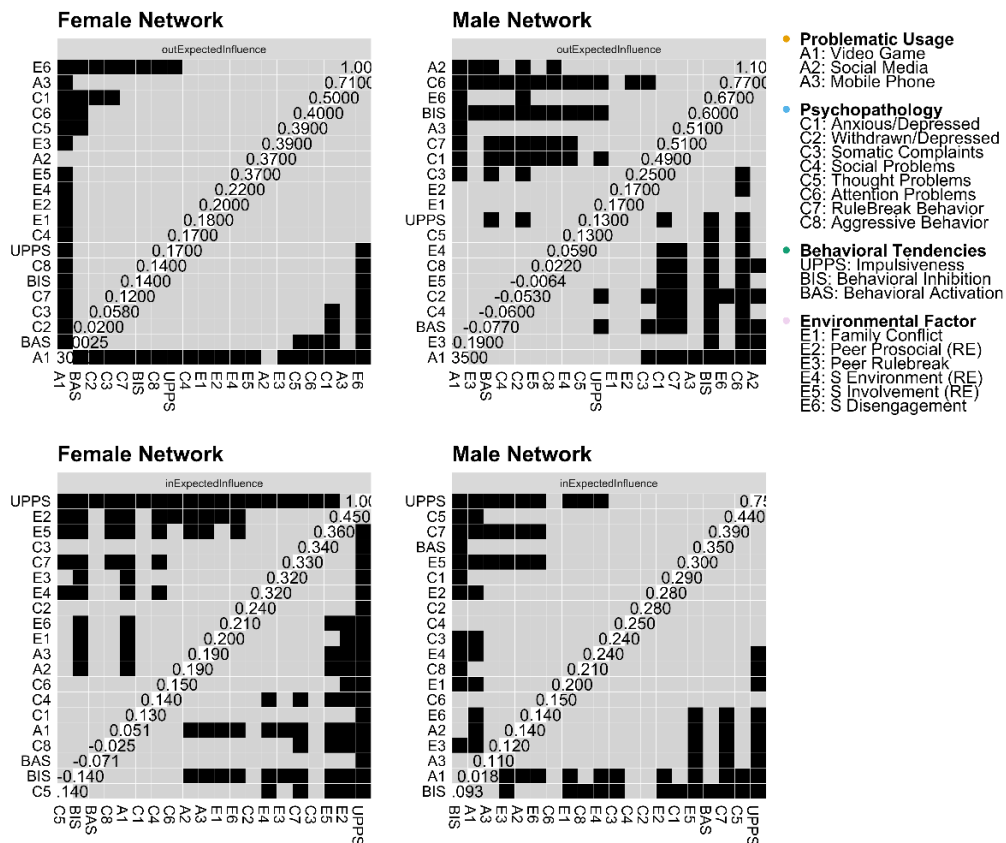
Index	Node1	Node2	Mean strength	Community of node1	Community of node2group
Female network					
1	A1	C3	-0.357	Problematic Usage	Psychopathology
2	A2	C3	0.302	Problematic Usage	Psychopathology
3	E6	UPPS	0.264	Environmental Factor	Behavior Tendencies
4	A2	C5	-0.251	Problematic Usage	Psychopathology
5	A1	C2	-0.248	Problematic Usage	Psychopathology
6	A1	C6	-0.229	Problematic Usage	Psychopathology
7	A3	UPPS	0.219	Problematic Usage	Behavior Tendencies
8	A1	BAS	-0.214	Problematic Usage	Behavior Tendencies
9	A3	BAS	0.194	Problematic Usage	Behavior Tendencies
10	A1	BIS	-0.186	Problematic Usage	Behavior Tendencies
Female network: about Problematic Usage					
1	A1	C3	-0.357	Problematic Usage	Psychopathology
2	A2	C3	0.302	Problematic Usage	Psychopathology
4	A2	C5	-0.251	Problematic Usage	Psychopathology
5	A1	C2	-0.248	Problematic Usage	Psychopathology
6	A1	C6	-0.229	Problematic Usage	Psychopathology
7	A3	UPPS	0.219	Problematic Usage	Psychopathological
8	A1	BAS	-0.214	Problematic Usage	Psychopathological
9	A3	BAS	0.194	Problematic Usage	Psychopathological
10	A1	BIS	-0.186	Problematic Usage	Psychopathological
11	A1	C5	-0.183	Problematic Usage	Psychopathology
Male network					
1	A2	BAS	0.315	Problematic Usage	Behavior Tendencies
2	A2	UPPS	0.308	Problematic Usage	Behavior Tendencies
3	E6	E5	0.205	Environmental Factor	Environmental Factor
4	A1	UPPS	-0.197	Problematic Usage	Behavior Tendencies
5	A2	C7	0.178	Problematic Usage	Psychopathology
6	E3	BIS	-0.177	Environmental Factor	Behavior Tendencies
7	E6	UPPS	0.154	Environmental Factor	Behavior Tendencies
8	A1	BIS	-0.153	Problematic Usage	Behavior Tendencies
9	A1	C2	-0.152	Problematic Usage	Psychopathology
10	C6	C5	0.151	Psychopathology	Psychopathology
Female network: about Problematic Usage					
1	A2	BAS	0.315	Problematic Usage	Behavior Tendencies
2	A2	UPPS	0.308	Problematic Usage	Behavior Tendencies
4	A1	UPPS	-0.197	Problematic Usage	Behavior Tendencies
5	A2	C7	0.178	Problematic Usage	Psychopathology
8	A1	BIS	-0.153	Problematic Usage	Behavior Tendencies

9	A1	C2	-0.152	Problematic Usage	Psychopathology
12	A3	UPPS	0.149	Problematic Usage	Behavior Tendencies
15	A2	A3	0.137	Problematic Usage	Problematic Usage
16	A2	BIS	0.133	Problematic Usage	Behavior Tendencies
20	A1	C6	-0.121	Problematic Usage	Psychopathology

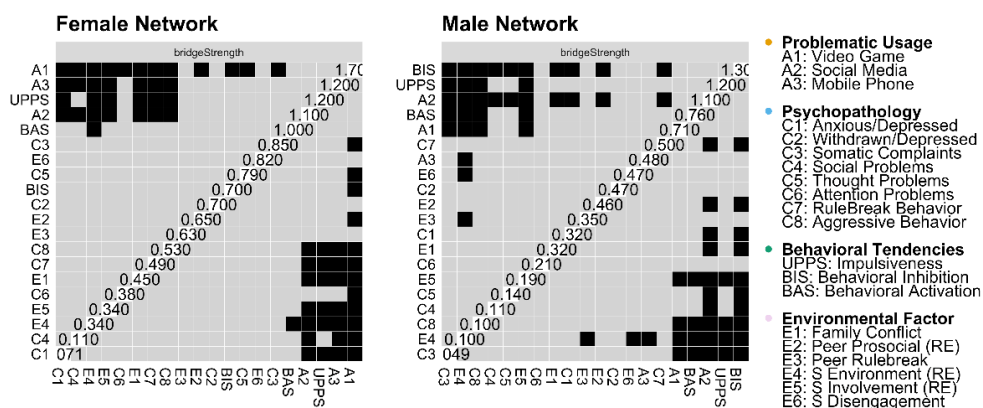
eFigure 14. Difference Test of Out- and In-Strength in CLPNs



Note. Nonparametric bootstrapped difference test for out-strength and in-strength provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

eFigure 15. Difference Test of Out-EI and In-EI in CLPNs

Note. Nonparametric bootstrapped difference test for out-EI and in-EI provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

eFigure 16. Difference Test of Bridge Strength in CLPNs

Note. Nonparametric bootstrapped difference test for bridge strength provided plots with gray boxes indicating no statistically significant difference and black boxes indicating a statistically significant difference. The central boxes display mean values.

4. Sensitivity Analyses for Imputation

To assess the robustness of the results, we conducted sensitivity analyses using pairwise deletion for missing values resulting from the absence of certain screen activities. This alternative approach treats people with non-use as having structurally missing data. Consequently, the data included in the cross-sectional network analysis were limited to participants who reported simultaneous use of social networking, video gaming, and smartphone activities. This analysis included 3,803 adolescents (1,715 girls, 45.10%) at T2 and 2,478 adolescents (1,001 girls, 40.39%) at T4. Due to differences in the study population, the connection strength in this new network significantly differed from that of the network constructed using minimum interpolation ($p < 0.05$). Nevertheless, the centrality of the problematic screen use indicator remained higher than that of screen time duration, further confirming the robustness of the observed patterns across different methods of handling missing data.

For the sensitivity analysis conducted on the CLPN models, we applied pairwise deletion for missing data due to the absence of specific screen activities. As a result, the analysis was restricted to adolescents who reported simultaneous use of social media, video games, and smartphones at both T2 and T4, which included 1,190 adolescents (469 girls, 39.41%). The results showed differences when compared to the CLPN models constructed using minimum value imputation, reflecting the limitations of the data. However, problematic screen use continued to demonstrate a significant negative impact on psychopathological factors, behavioral tendencies, and environmental factors, with its effect size significantly larger than the influence of environmental factors on psychopathological outcomes.

eTable 11. Demographics of the Sample After Pairwise Deletion

	2-year-follow-up (n = 3,803)			4-year-follow-up (n = 2,478)		
	Female n = 1,715	Male n = 2,088	p- value	Female n = 1,001	Male n = 1,477	p- value
Age, mean (SD), m	145.38 (7.99)	146.13 (7.91)	0.004	168.67 (7.86)	169.39 (8.10)	0.027
Race, No. (%)			0.661			0.003
White	987 (58%)	1,235 (59%)		630 (63%)	1,032 (70%)	
Black	370 (22%)	427 (20%)		147 (15%)	178 (12%)	
Asian	31 (1.8%)	31 (1.5%)		26 (2.6%)	38 (2.6%)	
Mixed/Other	327 (19%)	395 (19%)		198 (20%)	229 (16%)	
Ethnicity, No. (%)			0.208			0.675
Non-Hispanic	1,326 (77%)	1,578 (76%)		764 (76%)	1,138 (77%)	
Hispanic	389 (23%)	510 (24%)		237 (24%)	339 (23%)	
Parents Marital status, No. (%)			0.192			0.044
Married or living with a partner	1,154 (67%)	1,363 (65%)		711 (71%)	1,103 (75%)	
Single	561 (33%)	725 (35%)		290 (29%)	374 (25%)	
Parental Highest Education, No. (%)			0.546			0.340
High school or less	581 (34%)	688 (33%)		272 (27%)	376 (25%)	
College Education	1,134 (66%)	1,400 (67%)		729 (73%)	1,101 (75%)	

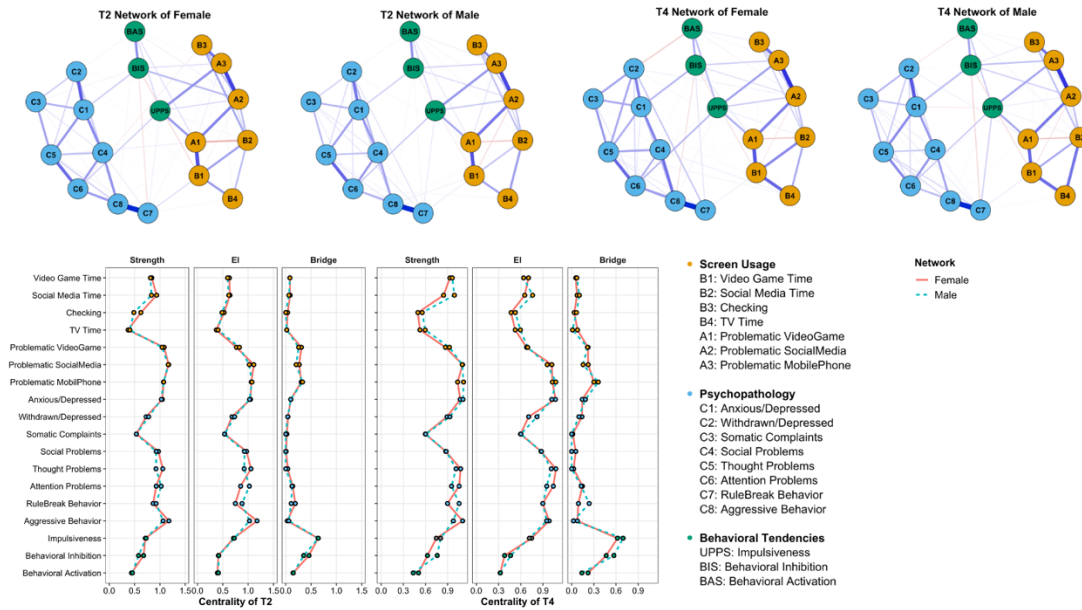
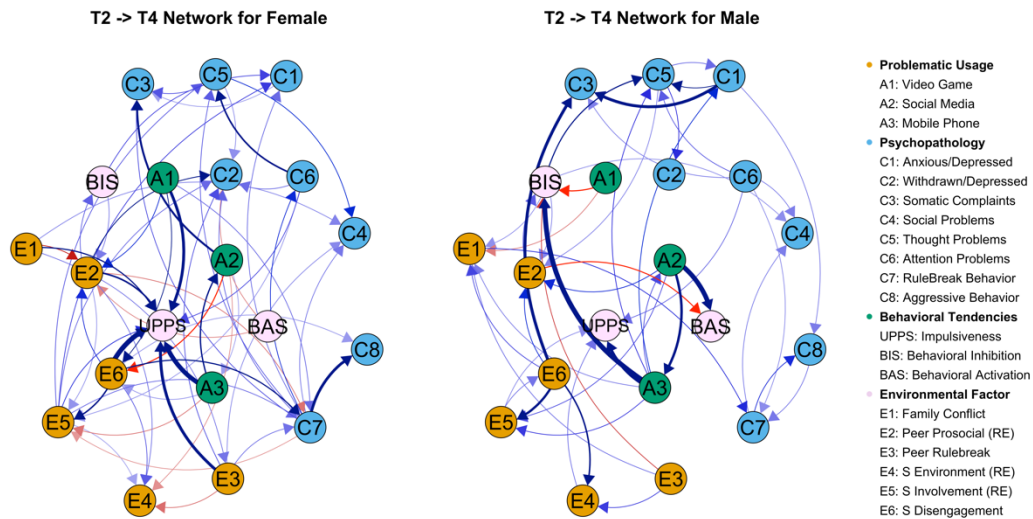
Family Income, No. (%)			0.899			0.295
<\$25,000	361 (21%)	462 (22%)		162 (16%)	242 (16%)	
\$25,000-\$49,999	295 (17%)	349 (17%)		168 (17%)	211 (14%)	
\$50,000-\$74,999	222 (13%)	280 (13%)		145 (14%)	187 (13%)	
\$75,000-\$99,999	235 (14%)	271 (13%)		142 (14%)	214 (14%)	
\$100,000-\$199,999	462 (27%)	546 (26%)		282 (28%)	456 (31%)	
\$200,000+	140 (8.2%)	180 (8.6%)		102 (10%)	167 (11%)	

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eTable 12. Demographics of the Sample After Pairwise Deletion

	T2 to T4 (n = 1,190)		
	Female (n = 469)	Male (n = 721)	p-value
Age at T2, mean (SD), m	144.38 (7.83)	144.81 (7.64)	0.349
Age at T4, mean (SD), m	169.63 (7.99)	170.30 (8.11)	0.162
Race, No. (%)			0.493
White	282 (60%)	461 (64%)	
Black	74 (16%)	112 (16%)	
Asian	11 (2.3%)	16 (2.2%)	
Mixed/Other	102 (22%)	132 (18%)	
Ethnicity, No. (%)			0.639
Non-Hispanic	346 (74%)	523 (73%)	
Hispanic	123 (26%)	198 (27%)	
Parents Marital status, No. (%)			0.725
Married or living with a partner	324 (69%)	505 (70%)	
Single	145 (31%)	216 (30%)	
Parental Highest Education, No. (%)			0.671
High school or less	142 (30%)	210 (29%)	
College Education	327 (70%)	511 (71%)	
Family Income, No. (%)			0.474
<\$25,000	75 (16%)	136 (19%)	
\$25,000-\$49,999	95 (20%)	124 (17%)	
\$50,000-\$74,999	69 (15%)	98 (14%)	
\$75,000-\$99,999	69 (15%)	93 (13%)	
\$100,000-\$199,999	120 (26%)	198 (27%)	
\$200,000+	41 (8.7%)	72 (10.0%)	

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eFigure 17. Cross-Sectional Networks After Pairwise Deletion**eFigure 18. CLPNs After Pairwise Deletion**

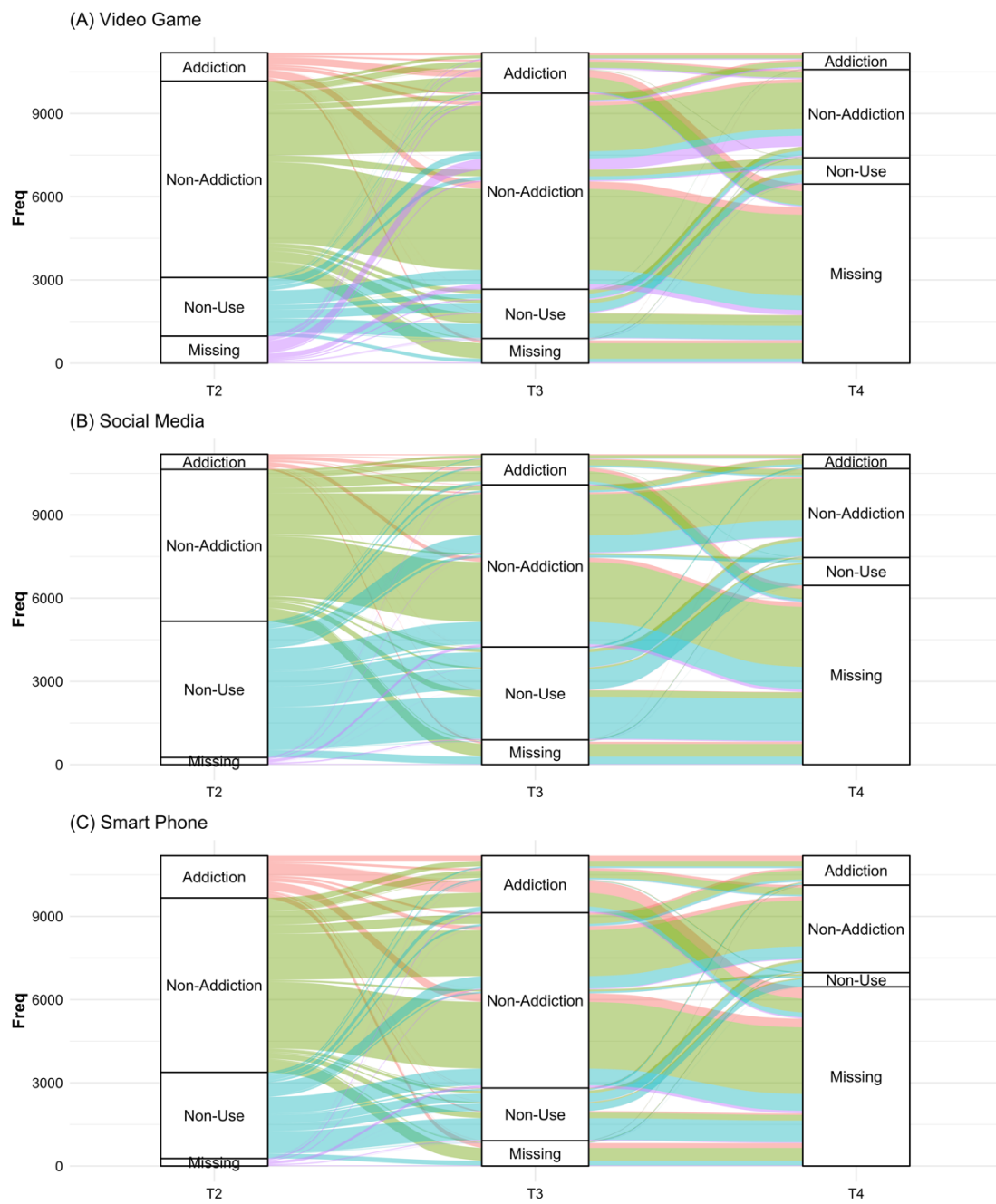
5. Sensitivity Analyses for Problematic Usage

To better capture the extent of adolescents' problematic screen use, we analyzed the data from the problematic screen use questionnaire as continuous variables. To further validate the stability of the results, we classified participants based on subclinical thresholds from three established scales. All subclinical thresholds were derived from previous research practices. Each screen activity was categorized into four groups: addiction, non-addiction, non-use, and missing. Specifically, for the Video Game Addiction Scale (VGAS) and the Social Media Addiction Scale (SMAS), participants were classified in the addiction group if at least 4 out of 6 items on the scale were rated above 3 (where 4 = sometimes, 5 = often, and 6 = very often) (Andreassen et al., 2012). For the 8-item Mobile Phone Involvement Questionnaire (MPIQ), participants were classified in the addiction group if their average score exceeded 4 (where 5 = Somewhat Agree, 6 = Agree, and 7 = Strongly Agree) (Choudhury et al., 2019). The full dataset included 11,189 participants (5,311 females, 47.46% female). The proportions of each category at the 2-year follow-up (T2), 3-year follow-up (T3), and 4-year follow-up (T4) are shown in eTable 11, and the transitions between categories are illustrated in eFigure 19.

Based on the categorical indicators, we conducted additional cross-sectional network analyses and CLPN models for both T2 and T4. The sample included in these analyses was consistent with that used under the continuous variable condition. In the cross-sectional network analysis, significant differences in both overall network structure and strength were observed when compared to the corresponding original networks. While some screen use duration or checking behavior frequency indicators still exhibited significant centrality differences when compared to their categorical counterparts, the reduction in centrality for problematic use indicators can likely be attributed to information loss during the transition from continuous to categorical data. In CLPN analyses, the categorical indicators of problematic screen use continued to demonstrate strong predictive power for other factors, further supporting their relevance in understanding adolescent developmental outcomes.

eTable 13. Classification of Problematic Screen Usage

	Female (n = 5,311)			Male (n = 5,878)		
	T2	T3	T4	T2	T3	T4
Video Game						
Addiction	177 (3.3%)	329 (6.2%)	154 (2.9%)	843 (14%)	1,129 (19%)	451 (7.7%)
Non-Addiction	3,000 (56%)	3,040 (57%)	1,292 (24%)	4,081 (69%)	4,027 (69%)	1,886 (32%)
Non-Use	1,765 (33%)	1,524 (29%)	814 (15%)	347 (5.9%)	249 (4.2%)	135 (2.3%)
Missing	369 (6.9%)	418 (7.9%)	3,051 (57%)	607 (10%)	473 (8.0%)	3,406 (58%)
Social Media						
Addiction	317 (6.0%)	667 (13%)	325 (6.1%)	231 (3.9%)	437 (7.4%)	197 (3.4%)
Non-Addiction	2,834 (53%)	2,848 (54%)	1,531 (29%)	2,641 (45%)	2,997 (51%)	1,673 (28%)
Non-Use	2,050 (39%)	1,380 (26%)	403 (7.6%)	2,860 (49%)	1,970 (34%)	600 (10%)
Missing	110 (2.1%)	416 (7.8%)	3,052 (57%)	146 (2.5%)	474 (8.1%)	3,408 (58%)
Smart Phone						
Addiction	880 (17%)	1,197 (23%)	665 (13%)	642 (11%)	860 (15%)	400 (6.8%)
Non-Addiction	3,032 (57%)	2,928 (55%)	1,381 (26%)	159 (2.7%)	490 (8.3%)	3,408 (58%)
Non-Use	1,286 (24%)	763 (14%)	211 (4.0%)	3,256 (55%)	3,391 (58%)	1,771 (30%)
Missing	113 (2.1%)	423 (8.0%)	3,054 (58%)	1,821 (31%)	1,137 (19%)	299 (5.1%)

eFigure 19. Transition of Problematic Screen Usage

eTable 14. Classification of the Sample in Cross-sectional Networks

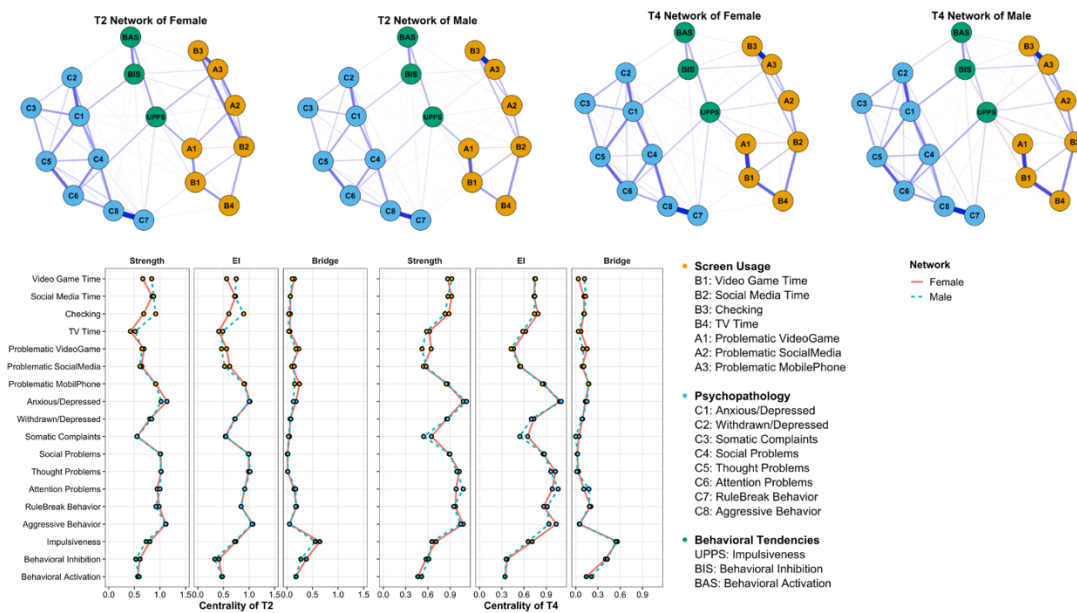
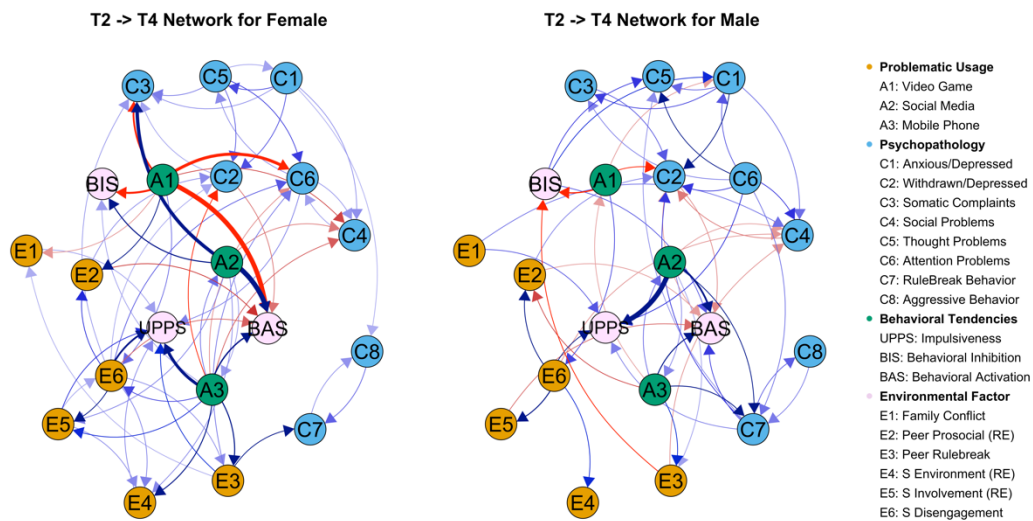
	2-year-follow-up (n = 9,054)			4-year-follow-up (n = 4,007)		
	Female (n = 4,272)	Male (n = 4,782)	<i>p</i> -value	Female (n = 1,896)	Male (n = 2,111)	<i>p</i> -value
VGAS			<0.001			<0.001
Addiction	138 (3.4%)	717 (16%)		137 (7.2%)	392 (19%)	
Non-Addiction	2,483 (61%)	3,389 (77%)		1,078 (57%)	1,590 (76%)	
Non-Use	1,435 (35%)	279 (6.4%)		678 (36%)	113 (5.4%)	
Missing	216	397		3	16	
SMAS			<0.001			<0.001
Addiction	270 (6.3%)	202 (4.2%)		281 (15%)	178 (8.5%)	
Non-Addiction	2,355 (55%)	2,203 (46%)		1,291 (68%)	1,407 (67%)	
Non-Use	1,633 (38%)	2,353 (49%)		321 (17%)	507 (24%)	
Missing	14	24		3	19	
MPIQ			<0.001			<0.001
Addiction	749 (18%)	552 (12%)		569 (30%)	351 (17%)	
Non-Addiction	2,514 (59%)	2,718 (57%)		1,155 (61%)	1,496 (71%)	
Non-Use	992 (23%)	1,476 (31%)		167 (8.8%)	246 (12%)	
Missing	17	36		5	18	

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eTable 15. Classification of the Sample in CLPN Models

	2-year-follow-up (n = 3,954)			4-year-follow-up (n = 3,954)		
	Female (n = 1,863)	Male (n = 2,091)	<i>p</i> -value	Female (n = 1,863)	Male (n = 2,091)	<i>p</i> -value
VGAS			<0.001			<0.001
Addiction	40 (2.4%)	270 (15%)		133 (7.2%)	376 (18%)	
Non-Addiction	975 (58%)	1,354 (77%)		1,059 (57%)	1,583 (76%)	
Non-Use	663 (40%)	130 (7.4%)		668 (36%)	115 (5.5%)	
Missing	185	337		3	17	
SMAS			<0.001			<0.001
Addiction	86 (4.6%)	63 (3.0%)		282 (15%)	168 (8.1%)	
Non-Addiction	1,006 (54%)	919 (44%)		1,269 (68%)	1,396 (67%)	
Non-Use	767 (41%)	1,104 (53%)		308 (17%)	508 (25%)	
Missing	4	5		4	19	
MPIQ			<0.001			<0.001
Addiction	289 (16%)	191 (9.2%)		559 (30%)	330 (16%)	
Non-Addiction	1,119 (60%)	1,205 (58%)		1,136 (61%)	1,485 (72%)	
Non-Use	451 (24%)	685 (33%)		163 (8.8%)	258 (12%)	
Missing	4	10		5	18	

Note. Two sample t-test for continuous variables; Pearson's chi-squared test for categorical variables.

eFigure 20. Cross-Sectional Networks for Classification Data**eFigure 21. CLPNs for Classification Data**

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